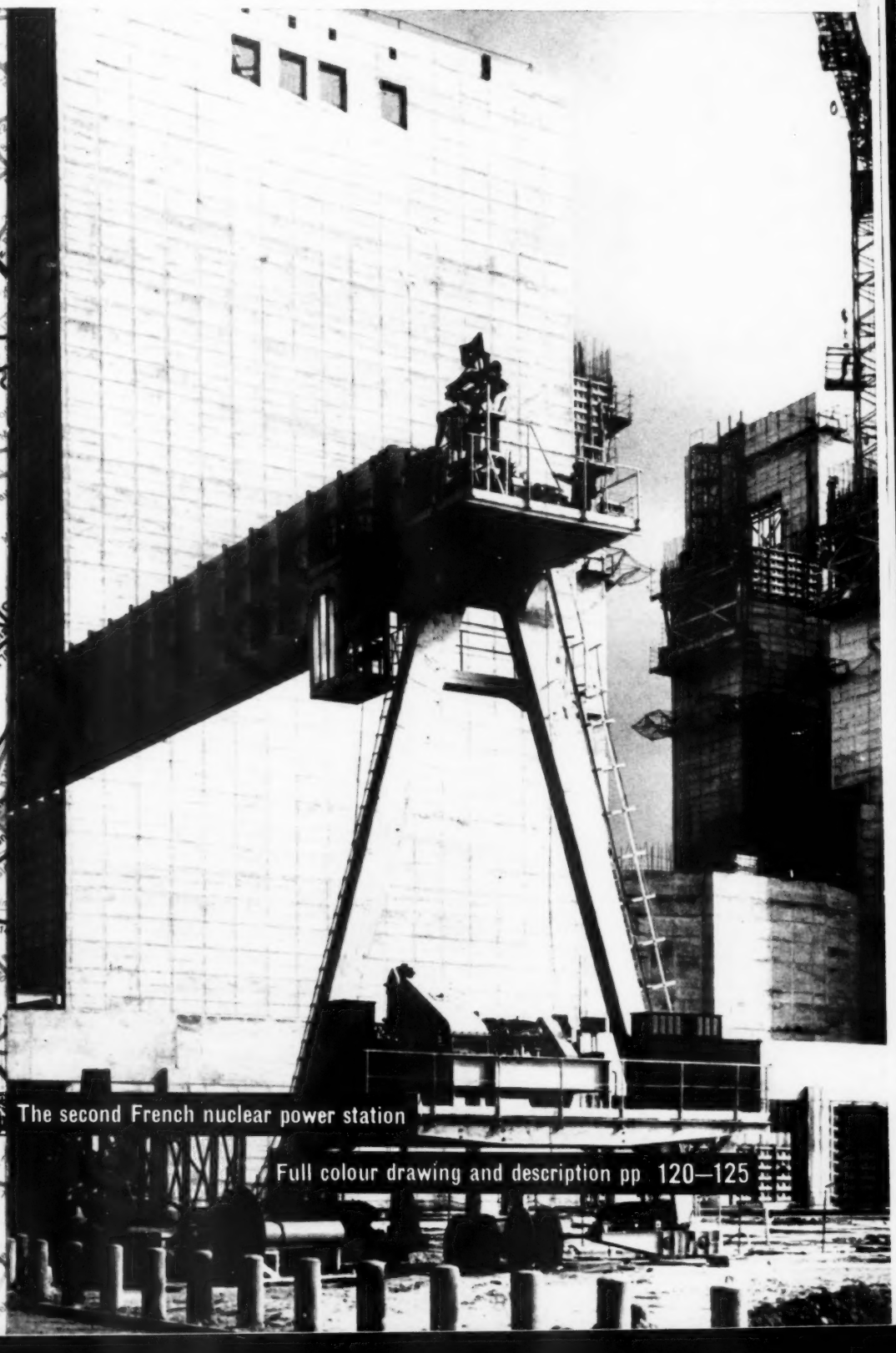
A ROWSE MUIR PUBLICATION

Nuclear Power

REACTORS · MATERIALS · INSTRUMENTATION · PROCESSES · RADIATION

Special issue

Atomic energy in France



The second French nuclear power station

Full colour drawing and description pp 120–125

SOLARTRON

Digital Data Recorder

50 or 100-channel operation

0.1% absolute accuracy

Low unit cost per channel

4-digit display and print-out

Commutation by gold-contact sealed relays

Rugged construction for on-site industrial use

gives rapid, accurate print-out of multichannel data for every industry

Write now for full details

THE SOLARTRON ELECTRONIC GROUP LTD.
Victoria Road, Farnborough, Hampshire
Tel: Farnborough (Hants) 3000

Nuclear Power

REACTORS · MATERIALS · INSTRUMENTATION · PROCESSES · RADIATION

VOL 5 NO 48 APRIL 1960

MANAGING DIRECTOR A. H. David Rowse, MA
EDITORIAL DIRECTOR Caldwell Davidson

EDITORIAL
EDITOR John Woodeson, BSC(ENG)
ASSISTANT EDITOR J. Burkett, FLA
TECHNICAL EDITOR David Iggulden, BSC

CONSULTANTS
INSTRUMENTATION Denis Taylor, PHD, MIEE, FIP
PHYSICS James F. Hill, BSC
METALLURGY Prof. J. G. Ball, BSC, FIM
ISOTOPES A. G. Maddock, MA, PHD, DIC

INDUSTRY GUIDE AND DIGEST NUMBER
EDITOR Charles E. Steiner

PRODUCTION
PRODUCTION MANAGER Gerald Vane, BA (CANTAB)
ASSISTANTS Donald Ewers, Gerald Withers

CIRCULATION
CIRCULATION MANAGER J. W. Rotheroe, BSC(ECON)
CIRCULATION ASSISTANT S. N. Ash

ADVERTISEMENTS
DIRECTOR Harry T. Kane
ADVERTISEMENT MANAGER John Abram
SOUTHERN REPRESENTATIVE K. M. Towell
CLASSIFIED ADVERTISEMENTS John Deamer

MANCHESTER OFFICE
Barry Gibbs
18 Grangeway, Handforth, Cheshire
tel: Wilmslow 2600

NEWCASTLE OFFICE
Peter Doig
17 Westgate Road, Newcastle 1
tel: Newcastle 24266

PARIS OFFICE
M. B. Lebovic & G. Leterrier,
36 rue du Fer-à-Moulin,
Paris 5eme, France
tel: POR 53-39

U.S. OFFICE
Walter J. Masterson, Jr
Box 206, Essex, Conn. *tel:* South 7-1838

HEAD OFFICE
The Rowse Muir Building,
77-79 Charlotte Street,
London, W.1, England
tel: Museum 8252
cables: ROWSEMUIR LONDON

NUCLEAR POWER is published by Rowse Muir Publications Ltd, and printed by The Haycock Press Ltd, SE5. The entire contents are protected by copyright in Great Britain and by the Universal Copyright Convention but matter may be reproduced provided that due acknowledgment is made to NUCLEAR POWER. Subscriptions to publishers Rowse Muir Publications Ltd. Single copies UK 3/6, 5/6 overseas, 75c US and Canada. One year's subscriptions UK and overseas £2.2.0, USA and Canada $8.00. Three years' subscriptions UK and overseas £5.0.0, USA and Canada $20.00.

SPECIAL FEATURES

ATOMIC ENERGY IN FRANCE

Introduction
Francis Perrin, High Commissioner of the Commissariat à l'Energie Atomique, writes a preface for this special issue on French activities 111

The power station programme
The plans of Electricité de France are described by the President, Marcel Flouret 112

Economics of nuclear power
J. Andriot, of the CEA, surveys the cost question 113

The legal position
J. Weinstein, of OEEC, outlines the basic law and its differences from UK practice 114

How industry is organized
Relations between national and private concerns in the atomic energy field are summarized by A. Mouturat, Secretary-General of ATEN 116

The CEA and its work
A look at the research and development establishments 117

The second nuclear power station
A Calder Hall type in concept, but very different in detail, EDF2 illustrates the French way of looking at reactor design. Full description by the chief designers 118

Cut-away perspective drawing of EDF2 in full colour facing page 116

French reactor instrumentation
Some recent examples show that making it smaller is still the main aim Editor: M. Surdin, head of Electronics Dept., CEA 124

Fuel handling on the plutonium reactors
G. Derome and A. Ertaud describe how a year's experience with G2 has thrown some interesting light on the design of fuel handling machinery 127

Radiation damage in iron and steels—2
Concluding a two-part article, Dr. D. Harries of Harwell reviews the effects on notched-bar properties and describes some current research 142

Health physics instrumentation—1
Dr. Taylor of Plessey Nucleonics introduces a new series by outlining the different instruments and their functions 147

US civilian power reactor programme 140

NUCLEAR TECHNOLOGY

REACTORS:

Developing new fuel elements
Current work at Saclay on both solid and dispersed types is described by J. Stohr and his team 133

MATERIALS:

Beryllium oxide—properties, problems and future
J. Elston of the CEA's metallurgy department sums up some recent French work on the effects of irradiation 131

PROCESSES:

Uranium production at Le Bouchet
The techniques used by the CEA, which differ in many respects from those in the UK and US, are outlined by H. Huet 130

PROGRESS IN INDUSTRY

Particle accelerators in France 136

The Marcoule plutonium extraction plant 137

Fuel element fabrication at Annecy 139

REGULAR FEATURES

Viewpoints	103	Points from Papers	156
Opinion	105	People	158
Worldview	107	Looking Ahead	160
Students' Notebook	141	Catalogues and Bulletins	160
Cross-Section *Gracchus*	146	Book Reviews	162
New Product Survey	149	Classified Advertisements	211
Industrial Newsdesk	152	Advertisers in this issue	214

RM ROWSE MUIR PUBLICATIONS LIMITED, LONDON, ENGLAND

SAINT-GOBAIN

atome

Prospecting for uranium ore

Production of metallic uranium

Through the S.E.T.U. (Société d'Etudes et de Travaux pour l'Uranium) construction at Narbonne, on behalf of the French Atomic Energy Commission, of a plant producing 1000 tons/year of uranium of nuclear purity.
This plant is operated by the S.R.U. (Société pour le Raffinage de l'Uranium)

Atomic fuel

Design and manufacture of fuel elements by the C.E.R.C.A. (firm specializing in atomic fuel).

Handling and mechanical treatment of irradiated fuel elements

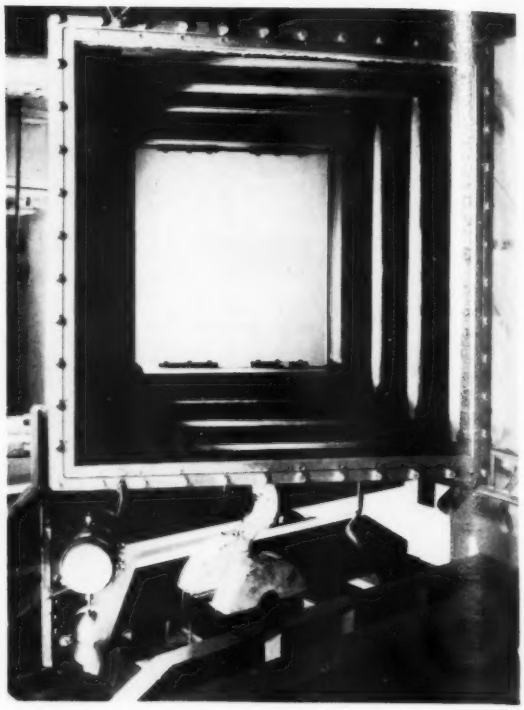
Design and construction of storage plant and mechanical decanning plant for irradiated fuel.
Construction for the C.E.A. of a plant for the mechanical decanning of the bars used by the G2 and G3 piles at Marcoule.

Chemical treatment of irradiated fuel

Reprocessing and metallurgy
Extraction of fission products

Hot laboratories fully equipped

Services Nucléaires SAINT-GOBAIN—19 Av. Georges Clémenceau, Courbevoie (Seine) FRANCE



Radiation shielding porthole built by SAINT-GOBAIN for the CHINON nuclear power station (ELECTRICITE DE FRANCE)

MARCOULE, FRANCE : Reprocessing Plant designed, built and set into operation by the Saint-Gobain Company for the French Atomic Energy Commission

Nuclear Power

REACTEURS · MATERIAUX · INSTRUMENTS · PROCEDES · RADIATION

VOL. 5 NO 48 AVRIL 1960

DIRECTEUR GENERAL A. H. David Rowse, MA
DIRECTEUR DE LA REDACTION Caldwell Davidson

REDACTION

REDACTEUR EN CHEF J. Woodeson, BSC
REDACTEUR EN CHEF—ADJOINT J. Burkett, FLA
REDACTEUR EN CHEF—TECHNIQUE D. Iggulden, BSC

CONSEILLERS

INSTRUMENTS Denis Taylor, PHD, MIEE, FIP
PHYSIQUE James F. Hill, BSC
METALLURGIE Prof. J. G. Ball, BSC, FIM
ISOTOPES A. G. Maddock, MA, PHD, DIC

GUIDE ANNUEL POUR L'INDUSTRIE

REDACTEUR EN CHEF Charles E. Steiner

PRODUCTION

DIRECTEUR DE LA PRODUCTION Gerald Vane, BA
ADJOINTS Donald Ewers, Gerald Withers

DIFFUSION

DIRECTEUR DE LA DIFFUSION J. Rotheroe, BSC
ADJOINT S. N. Ash

PUBLICITE

DIRECTEUR Harry T. Kane
DIRECTEUR DES ANNONCES John Abram
REPRESENTANT SUD K. M. Towell
PETITES ANNONCES John Deamer

BUREAU DE MANCHESTER

Barry Gibbs,
18 Grangeway, Handforth, Cheshire
tel: Wilmslow 2600

BUREAU DE NEWCASTLE

Peter Doig,
17 Westgate Road, Newcastle 1
tel: Newcastle 24266

BUREAU DE PARIS

M. B. Lebovic & G. Leterrier,
36 rue du Fer-à-Moulin,
Paris 5eme, France
tel: POR 53-39

BUREAU DES ETATS-UNIS

Walter J. Masterson Jr,
Box 206 Essex Conn.
tel: South 7-1838

BUREAU CENTRAL

The Rowse Muir Building,
77-79 Charlotte Street,
Londres, W1, Angleterre
tel: Museum 8252
cables: ROWSEMUIR LONDON

NUCLEAR POWER est publié par Rowse Muir Publications Ltd, et imprimé par The Haycock Press Ltd, Londres SE5.

Tous droits de reproduction réservés en Grande-Bretagne et par la convention universelle des droits d'auteur. Reproduction autorisée si mention de l'origine: NUCLEAR POWER est faite.

Abonnement aux éditeurs: Rowse Muir Publications Ltd. Le numéro: Royaume-Uni 3/6, Outre-mer 5/6, Etats-Unis et Canada 75 cents. Abonnement d'un an Royaume-Uni et Outre-mer £2.2.0, Etats-Unis et Canada $8.00. Abonnement de trois ans: Royaume-Uni et Outre-mer £5.0.0, Etats-Unis et Canada $20.00.

ARTICLES PRINCIPAUX

L'ENERGIE ATOMIQUE EN FRANCE

Avant-propos
M. Francis Perrin, Haut Commissaire du Commissariat à l'Energie atomique, préface ce numéro spécial sur les réalisations françaises 111

Programme des centrales nucléaires
Par M. Marcel Flouret, Président d'Electricité de France 112

L'économie de l'énergie nucléaire
M. Andriot, du CEA, examine le problème des coûts 113

La position juridique
M. Weinstein, de l'OECE, esquisse le droit fondamental et ses différences à l'égard des pratiques du Royaume-Uni 114

Comment l'industrie est-elle organisée
Les relations entre les enterprises du secteur public et des secteurs privés examinés par M. Mouturat, Secrétaire Général de l'ATEN 116

Le CEA et son travail
Coup d'oeil sur les établissements de recherche 117

La deuxième tranche de la centrale nucléaire de Chinon
Du type Calder Hall, mais très différente dans sa conception, EDF2 *montre la manière dont les Français envisagent la construction des réacteurs. Description complète par les principaux auteurs du projet* 118

Dessin en perspective d'EDF2 en couleurs en face de la page 116

Instrumentation des réacteurs français
Certains exemples récents montrent que le but essentiel continue à être de réduire les dimensions. Etabli sous la direction de M. Surdin, chef du service d'électronique au CEA 124

La manutention du combustible dans les réacteurs plutonigène
MM. Derome et Ertaud montrent comment une année d'expérience à G2 *influe sur la conception des machines de manutention du combustible* 127

Effets de l'irradiation sur le fer et l'acier—2
Conclusion d'un article en deux parties, par le Dr. D. Harries, de Harwell sur les effets sur les caractéristiques des éprouvettes entaillées, avec description de certaines recherches effectuées récemment à Harwell 142

Instruments de radiophysique médicale et sanitaire—1
Avant-propos d'une série d'articles, dans, lequel le Dr. Taylor place le sujet dans l'optique qui convient et décrit les différents instruments et leurs rôles 147

Le Programme des réacteurs aux Etats-Unis 140

TECHNOLOGIE NUCLEAIRE

REACTEURS :

Le développement d'éléments combustibles nouveaux
Le travail courant à Saclay sur les types dits solides et à dispersion est décrit par M. Stohr et ses collaborateurs 133

MATERIAUX :

L'oxyde de béryllium, ses propriétés, ses problèmes et son avenir
M. Elston de la Section Métallurgique du CEA donne un aperçu de quelques expériences françaises récentes sur les effets de l'irradiation 131

PROCEDES :

La production d'uranium au Bouchet
Les procédés techniques employés par le CEA, qui diffèrent par beaucoup d'aspects de ceux pratiqués en Grande Bretagne et aux Etats-Unis, sont décrits par M. Huet 130

PROGRES INDUSTRIELS

Les accelérateurs de particules français 136

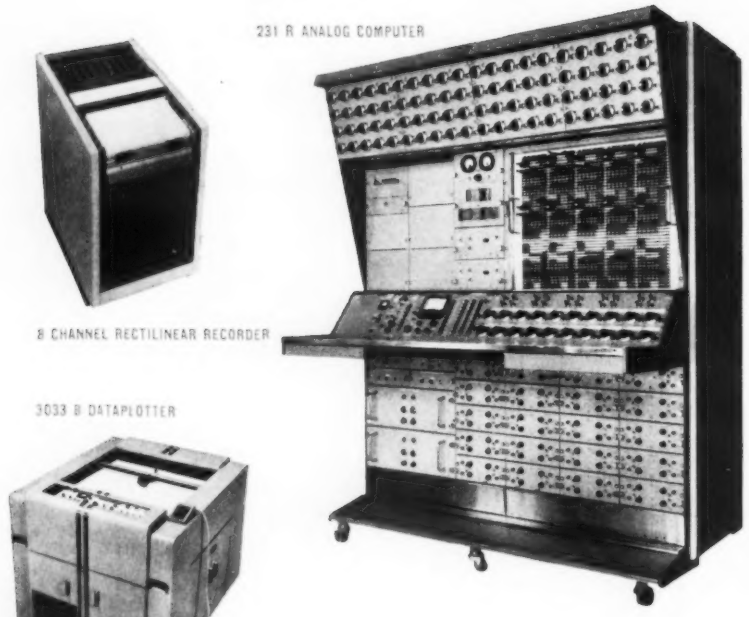
L'installation d'extraction de plutonium de Marcoule 137

Fabrications d'éléments combustibles à Annecy 139

CHRONIQUES HABITUELLES

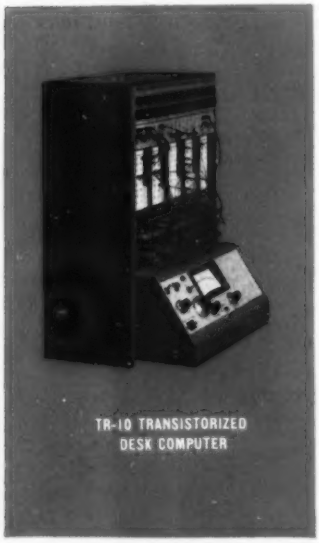
Points de vue	103	Extrait d'articles	156
Opinion	105	Personnalités	158
Tour d'horizon mondial	107	L'Avenir	160
Le carnet de l'étudiant	141	Catalogues et Bulletins	160
La page de Gracchus	146	Revue de Livres	162
Revue des Nouveaux Produits	149	Petites annonces	211
Bureau Industriel	152	Annonceurs dans ce numéro	214

RM ROWSE MUIR PUBLICATIONS LIMITED, LONDRES, ANGLETERRE



E.A.I. SETS THE PACE IN INSTRUMENTATION

Electronic Associates, the world's largest manufacturer of General Purpose Analog Computers, now offers European industry a complete line of PACE Instruments to help solve all types of Computation, Data Handling and Instrumentation problems. The high quality of PACE Equipment is guaranteed by Electronic Associates' reputation and experience as the leading producer of Analog Computers for over eight years :



The above photo shows several of the PACE line of Instruments which are available

231 R ANALOG COMPUTER. Newest addition to the world famous line of PACE Analog Computers. Capacity : 20 to 100 amplifiers and related nonlinear equipment. 0.01 % precision. Manual or Digital Potentiometers. Optional ADIOS system (Automatic Digital Input Output System).

TR-10 TRANSISTORIZED DESK COMPUTER. Capacity 20 amplifier and nonlinear units. Precision 0.1%. Compactness, low power consumption and low voltage levels makes this an ideal nucleus for on-line computation of process control applications. Useful in laboratory and educational institutions.

DATAPLOTTER, TYPE 3033 B. For high speed conversion and plotting of digital input information into analog graphs. Point or Continous line plotting. Speed 60 points per minute. Precision : 0.05%. Works from IBM cards, paper tape and manual keyboard.

8-CHANNEL RECTILINEAR RECORDER. Accurate and high speed recording oscillograph. Includes chopper stabilized amplifier, push button chart speed and sensitivity control and heated stylus recording.

MODEL 1100E VARIPLOTTER. X-Y plotter for Computer and general laboratory use. .075 % Static Accuracy. With wide range of input sensitivities and vacuum holddown. Can also be used as function generator.

MODEL 26.070 TRANSISTORIZED DIGITAL VOLTMETER. A general purpose readout instrument for high speed digital readout of analog voltages. Average speed · 200 readings per second. Accuracy :0.01 % Includes reference and power supplies. Can be operated with EAI model 39.034 high speed Printer.

Skilled sales and application engineers from Electronic Associates stand ready to assist European industries of all types in solving their systems and instrumentation problems.

DETAILS OF OUR COMPLETE LINE OF PACE COMPUTERS AND INSTRUMENTS WILL BE SENT UPON REQUEST.

EAI

ELECTRONIC ASSOCIATES LTD. Works and Head Office : Victoria Road - Burgess Hill - Sussex - England.
Tel. Burgess Hill 26.36. Telex : PACE BURGESSHL

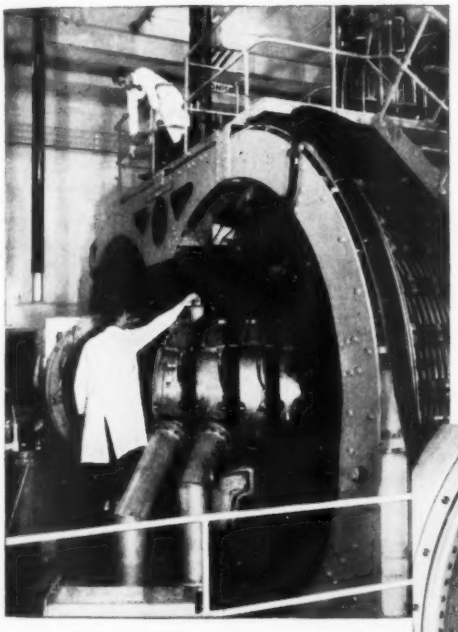
ELECTRONIC ASSOCIATES Inc. European Computation Center and Continental Sales Office
43, rue de la Science Brussels 4 - Belgium. Tel. 11.43.69. Telex : PACE BELGBRU.

PRODUCERS OF
PACE
ANALOG COMPUTERS
REGISTERED TRADEMARK

TEDDINGTON BELLOWS
and Nuclear Power
HARWELL PAYS A TRIBUTE

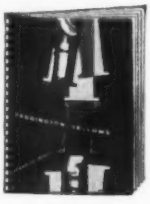
Harwell top research scientists have freely acknowledged * that recent improvements in the operational efficiency of Zeta owe much to the introduction of a corrugated stainless steel liner inside the aluminium 'torus'. Having decided to use such a liner, they turned to Teddington engineers who, out of their experience in adapting their bellows expansion joints to various demands in a wide field of industry, produced exactly what was required for satisfactory running over long periods.

* *In a paper read before the I.E.E. on 29/30 April 1959 by Mr. J. T. D. Mitchell of the U.K.A.E.A., Harwell*



In Zeta, experiments towards controlling fusion have resulted in gas temperatures of several million degrees centigrade being achieved for millisecond periods. View showing the torus.

This stainless steel liner has improved operational characteristics and requires less maintainance than the original aluminium liner system. Here is part of the twelve welded sections of Teddington stainless steel bellows tube of wall thickness 0·017″; it has 2½ convolutions per inch of a depth of 0·75″. The bellows is 38 inch bore and the whole toroidal bellows assembly has an axial length of 37 feet and an electrical resistance of 0·02 ohms.



SEND FOR HANDBOOK R.43

Illustrated descriptions are given of the many and varied problems that Teddington Bellows Expansion Joints can overcome. If you did not secure your copy at the Engineering Exhibition, please write for one.

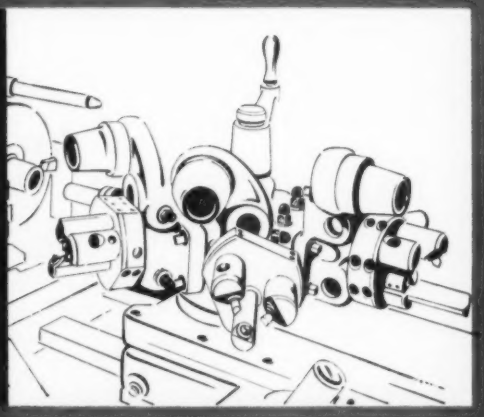
ZETA

Made under licence from the Solar Aircraft Co., California, U.S.A.

TEDDINGTON
STAINLESS STEEL BELLOWS

TEDDINGTON AIRCRAFT CONTROLS LTD. (*Industrial Bellows division*)
Ammanford, Carms. Tel.: Ammanford 2255

FREE CUTTING BRONZES AND BRASSES



- Free Cutting Brass for use at the highest machine speeds. Available as rods, bars, tubes, solids and hollow shapes.
- High strength Bronzes and Brasses with good machining properties.
- Close metallurgical control at all stages of manufacture.
- Alloys produced to all British and other standard specifications.

THE MANGANESE BRONZE AND BRASS COMPANY LIMITED

HANDFORD WORKS HADLEIGH ROAD IPSWICH
TELEGRAMS: BRONZE IPSWICH
TELEPHONE: IPSWICH 53127

Worried about Corrosion?

then write for these booklets

These publications give information on the behaviour of nickel and *Monel*, *Corronel 210*, *Ni-o-nel* and *Inconel* corrosion resisting alloys when in contact with many different corrosive media. The results of research and practical experience in both Europe and America are reported and many examples are shown of these materials in use in chemical plant.

SEND THIS COUPON for copies of the particular CORROSION BOOKLETS you require.

(Please tick in spaces provided)

CORROSION-RESISTING CHARACTERISTICS OF WIGGIN HIGH-NICKEL ALLOYS ☐

WIGGIN NICKEL ALLOYS V. FLUORINE AND FLUORINE COMPOUNDS ☐

WIGGIN NICKEL ALLOYS V. HYDROGEN CHLORIDE AND HYDROCHLORIC ACID AND CHLORINE ☐

WIGGIN NICKEL ALLOYS V. CAUSTIC ALKALIES ☐

NAME _____

COMPANY & ADDRESS _____

_____

APPOINTMENT or DEPARTMENT _____

NP/C11/4

Wiggin publications help in the choice of suitable materials. Our corrosion engineers have accumulated data on the performance of many metals and alloys in most of the corrosive environments met in industry. Advice and information are freely given.

'Monel', 'Corronel', 'Ni-o-nel' and 'Inconel' are Registered Trade Marks.

HENRY WIGGIN & COMPANY LIMITED
WIGGIN STREET · BIRMINGHAM 16

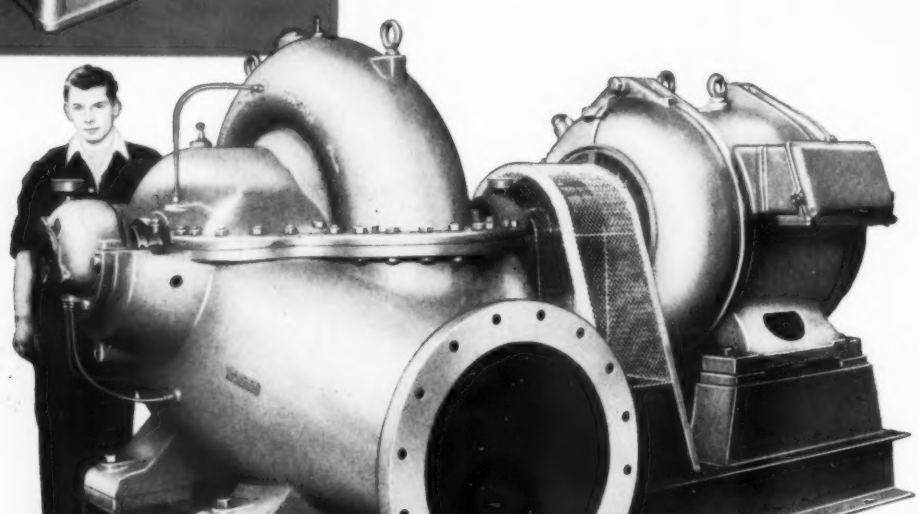
TGA C11

Tick **No 6** on reply card for further details

15 or 15,000 g.p.m.

WS features mean better service

Type 'L' pumps of split case construction provide easy access to the interior without disturbing pipe or shaft connections. Above all Worthington-Simpson reliability means long and efficient service with the minimum attention and maintenance costs. This versatile range covers capacities from 15 to 15,000 g.p.m.; heads up to 600 feet.



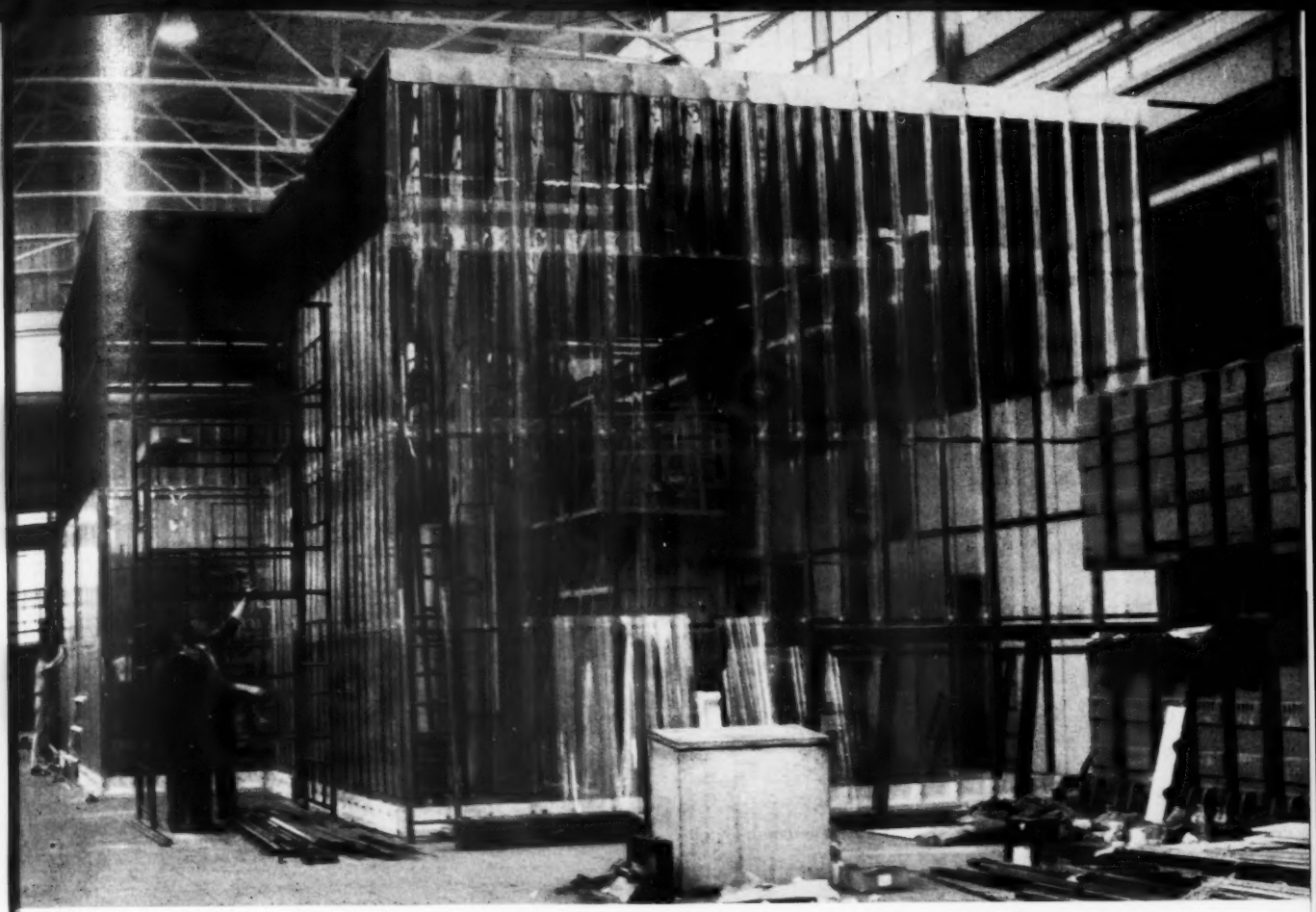
TYPE 'L' SINGLE STAGE VOLUTE PUMPS

Worthington - Simpson Ltd

PUMPS • COMPRESSORS • HEAT EXCHANGE EQUIPMENT

WS

NEWARK NOTTS



another problem solved with UNISTRUT

Insulated enclosure for machining 7GeV synchrotron core

An unusual temperature control problem was encountered by Messrs. Joseph Sankey Ltd. in the machining of 336 sectors, each accurate to within half of one degree, which will form the core of the Commonwealth's largest electro-magnet. When assembled, this will measure 160 ft. across, yet the throat faces must be parallel to within .004 inches.

2,700 sq. ft. Unistrut enclosure

To ensure dimensional stability, machining takes place in an insulated booth where the temperature has a maximum variation of 0.75° C. Measuring 80 ft. x 34 ft. x 20 ft. 9 in., with three sliding hatches and four 20 ft. high Unistrut doors for introduction and removal of the 20-ton sectors, the booth consists of a Unistrut framework, incorporating a 27 ft. truss also of Unistrut: it is clad on three sides with Perspex, on the fourth with Menotex sheeting, and roofed with Asbestolux.

No interference with production

The framework itself was rapidly assembled using standard Unistrut channels and self-locating nuts; the members are spaced to accept standard sized sheets with little or no cutting, thus conserving material and reducing on-site labour costs. The entire installation apart from the hatches was completed in one week-end, avoiding production hold-ups. As the enclosure will be required in its present form for only twelve months, Unistrut's facility for layout alterations is an added advantage; alternatively, the structure can be entirely dismantled and its materials freed for other use.

Wide range of applications

'Space division' is only one field in which Unistrut's rapid, rigid assembly and wide component range assist planning and reduce on-site time and cost. For further information on its use in pipe support, electrical trunking, instrument mounting, etc., please write to the address below.

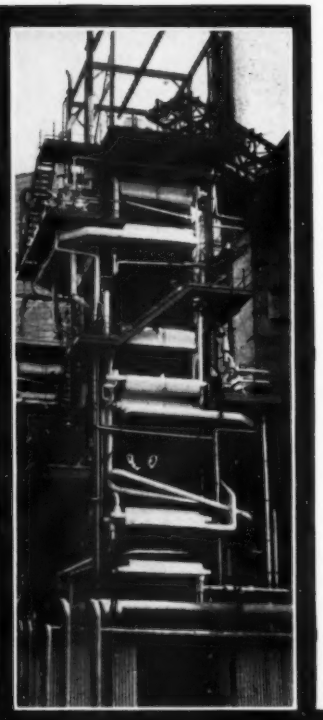
UNISTRUT STEEL CHANNEL FRAMING SYSTEM

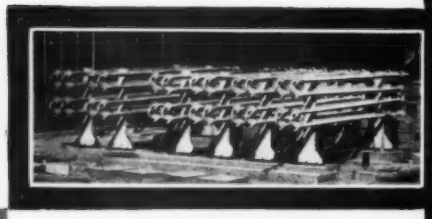
Unistrut Division of Sankey-Sheldon Ltd. A member of the Guest, Keen & Nettlefolds Group of Companies

43-45, Broadwater Road, Welwyn Garden City, Herts. Telephone: Welwyn Garden City 6321 (4 lines)

UNI306

Calder Hall
Chapelcross
Berkeley
Hunterston
Bradwell
Hinkley Point





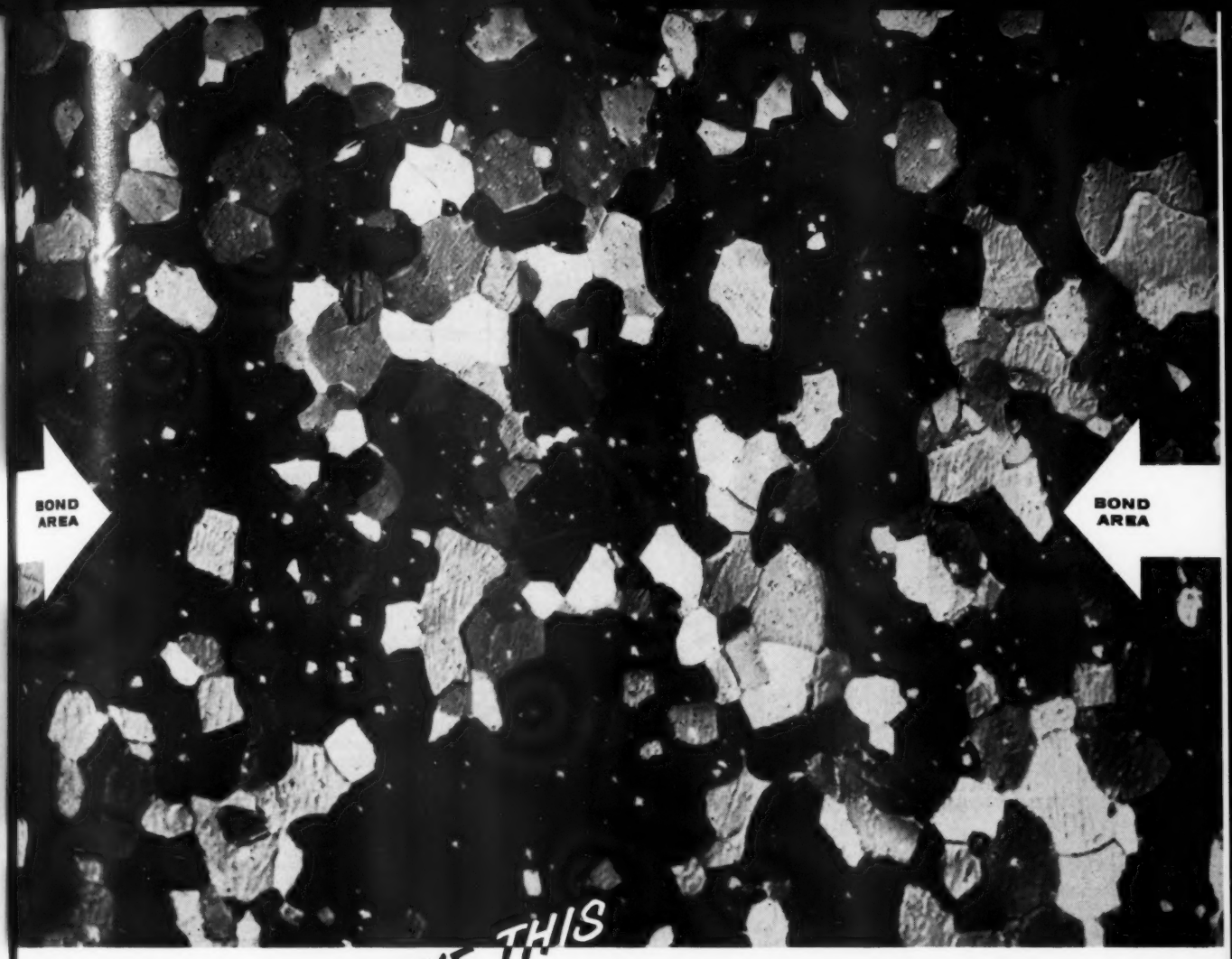
DCL know CO_2

The Distillers Company Limited
Chemical Division—Carbon Dioxide Department
Devonshire House, Piccadilly, London W.1
Telephone: Mayfair 8867

The use of carbon dioxide as a heat transfer medium in nuclear power stations raises many problems. Where storage and vaporization are concerned, The Distillers Company Limited know the answers; and they provided the installations for the purpose at both Calder Hall and Chapelcross.

Other similar, even larger, installations are now being designed or constructed by the Company for the Berkeley, Hunterston and Hinkley Point power stations. The Company has recently also obtained the contract for the supply of carbon dioxide to the Bradwell and Hinkley Point nuclear power stations.

TA/253



LIKE THIS

BONDS ARE OUR BUSINESS

A high-integrity metallurgical bond between fuel and cladding is your best guarantee against void-induced fuel cladding failures.

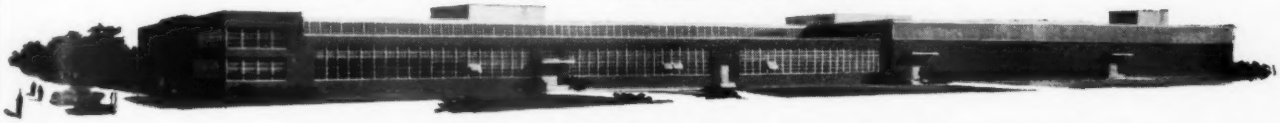
Element processing that eliminates bond line defects and exhibits grain growth across interfaces can enhance fuel life and reactor performance.

M & C Nuclear's superior experience and technical knowledge in bonding metals is widely recognized in the nuclear industry. Elements bonded by hot rolling, cold rolling, coextrusion, brazing, welding, and pressing have been made in production quantities. We are also equipped to check the integrity of our bonds by metallographic examination and the nondestructive methods such as radiography and ultrasonic testing.

Our bonding skill is another reason that M & C Nuclear fuel elements contribute to efficient reactor operations. Let us confer with you in an early stage of your reactor design project to assure the greatest economies in fuel element utilization.

Another example of M & C's technical skills in the nuclear industry.

TEXAS INSTRUMENTS
INCORPORATED
M&C NUCLEAR, INC.
(A SUBSIDIARY)
P. O. BOX 898 • ATTLEBORO, MASSACHUSETTS, U. S. A.



The World's Largest Privately Owned Facility Designed Specifically for Fabrication-Development and Production of Fuel Elements, Core Components and Complete Cores.

THE FRENCH NUCLEAR INDUSTRY

On the following pages will be found many of the firms supporting the French nuclear programme. They are advertising here because of NUCLEAR POWER'S wide circulation in nearly every country in the world

ATEN

Established in 1955 under the sponsorship of the French Atomic Energy Commission and Electricité de France (French National Power Company), A.T.E.N. is an association of most of the companies involved in the use and development of nuclear power. It is a non-profit organization, dedicated to promoting the use of nuclear energy.

For this purpose

1 A.T.E.N. establishes a general information service for the benefit of its members.
2 A.T.E.N. informs its membership of the facilities and potentialities of member companies in the nuclear field.
3 A.T.E.N. publicises the French atomic industry at home and abroad.
4 A.T.E.N. publishes a periodical bulletin designed to give information in the nuclear field, to inform the members of the activities of the association and of the accomplishments of member companies.
5 A.T.E.N. sponsors symposia, conferences, meetings, and participates in various technical exhibitions.

TECHNICAL ASSOCIATION FOR THE PRODUCTION AND UTILIZATION OF NUCLEAR ENERGY

4 rue de Téhéran PARIS (8e)

Tick **No 11** on reply card for further details

industries atomiques

INDUSTRIES ATOMIQUES

is the only international technical and industrial review printed in French, which specialises entirely in nuclear and related subjects.

INDUSTRIES ATOMIQUES is read by industrialists, engineers, technicians and chemists, heads of technical firms and by all those engaged in the world of science. In short, it is intended expressly for all specialists interested in research and in its practical realisation.

In view of its international character, **INDUSTRIES ATOMIQUES** is read and appreciated in countries all over the world.

Up to date, more than 250 authors, all specialists, have honoured this review with their collaboration, and have contributed **previously unpublished** articles of high scientific value, abundantly illustrated.

INDUSTRIES ATOMIQUES is a source of precise documentation, constantly being brought up to date. The international information and the list of suppliers to the atomic industries printed in its pages will be found invaluable.

The international review for the peaceful uses of nuclear energy
A RENE KISTER PUBLICATION

Annual Subscription

12 numbers per year

French new francs	41,50
Belgian francs	510
Swiss francs	40
German marks	35
U.S. dollars	8.50
Pounds sterling	3

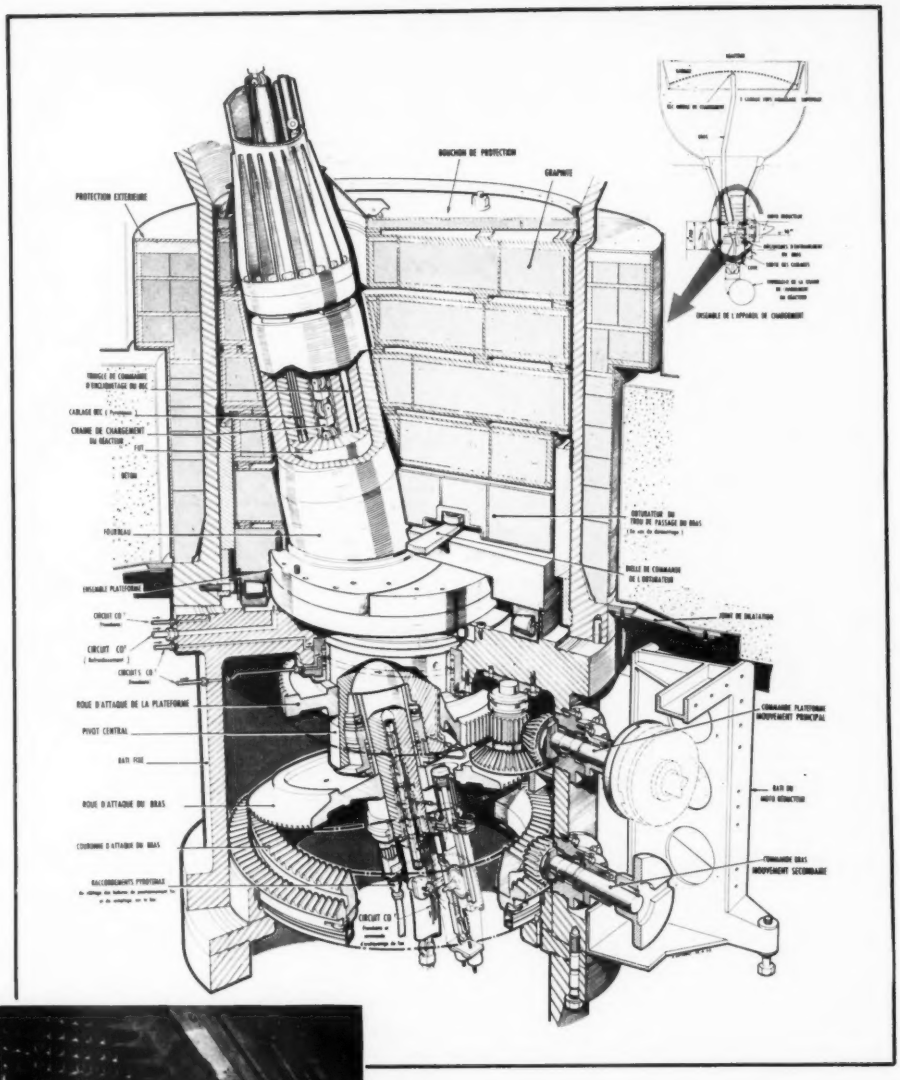
Industries Atomiques Subscription form

Subscriptions can be paid in the currency of the country at any European post office.

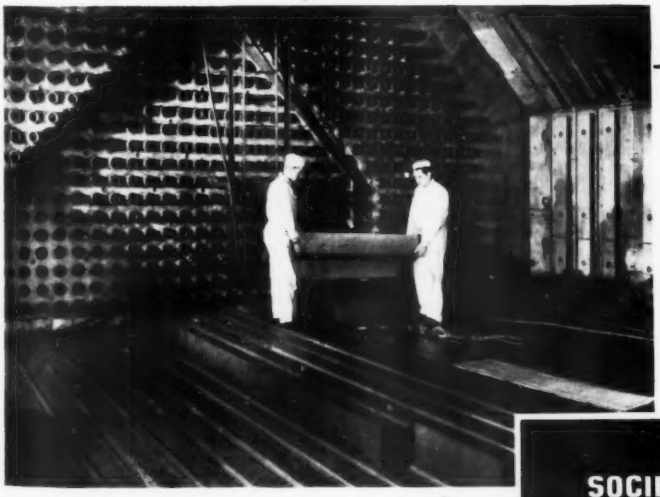
We desire _____ annual subscriptions, starting from _____, to be sent to (surname, Christian names, or firm's name, and address) _____

Method of payment _____ Date and signature:

(This form should be returned in a stamped and addressed envelope to NUCLEAR POWER, 3 Percy Street, London, W1.)



Loading and unloading device designed to operate through the lower section of the reactor developed by S. F. A. C. for EDF 1 Power Plant.



Graphite Stack in G2 Reactor
S. F. A. C. will produce the stacks for EDF 1 and EDF 2 Reactors

The activities of
The SOCIÉTÉ DES FORGES ET ATELIERS DU CREUSOT
in the field of Nuclear Power :
Engineering Study
Construction of Reactors
and associated mechanical equipment

SOCIETE DES FORGES ET ATELIERS DU CREUSOT (USINES SCHNEIDER)

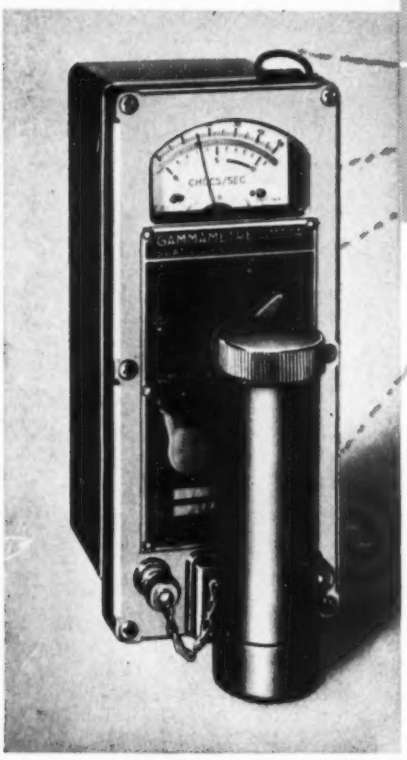
F S C A

Head Office : 15 rue Pasquier - PARIS - FRANCE
Phone : ANJOU 34-40 - Cables : FORGEAC-PARIS

DETECTEURS

de rayonnements nucléaires

RADIATIONS NUCLEAR DETECTOR



GAMMAMÈTRES ET ACCESSOIRES

GEIGER COUNTERS AND ACCESSORIES

Les Gammamètres SRAT et leurs accessoires servent pour toutes les mesures courantes des rayonnements GAMMA et BETA.

Ce Gammamètre sert à la prospection de surface et dans tous les cas où l'on exige une grande sensibilité et une mesure stable.

Il est d'une conception extrêmement robuste et fonctionne sous tous les climats

- Détecteur : 3 compteurs 3 G 12.
- Surface : 180 cm2
- Gammes : 5.000 - 500 - 50 c s AVP ou 1.250 - 125 - 12.5 c s sur compteur externe.
- Pertes de comptage inférieures à 10 %.
- Constante d'intégration adaptée à chaque gamme avec une position supplémentaire à grande constante sur la première échelle.
- Alimentation : par 2 piles de 1.5 volt.
- Autonomie : 24 heures en régime permanent ou 5×8 heures en régime intermittent.
- Dimensions : 232×180×97.
- Poids : 2.9 kgs.

The Geiger Counters and their accessories manufactured by SRAT have been designed for every usual measurement for GAMMA and BETA Radiations.

This instrument is designed for surface prospection whenever a high sensitiveness and a steady reading are required.

It is featuring a very robust construction and it is convenient for operation under any climate conditions.

- *Detecting element : 3×3G 12 (LCT).*
- *Total surface 180 cms.*
- *Ranges : 5.000 - 500 - 50 AVP counts s or 1.250 - 125 - 12.5 c s with external counter.*
- *Losses in counting : smaller than 10 %.*
- *Integration time : individually calculated for each range with a high time constant position of the switch on the first scale.*
- *Current supply by 2 usual, 1.5 V batteries ensuring a 24 hours continuous operation time or a 5×8 hours intermittent operation time.*
- *Dimensions : 232×180×97 m m.*
- *Weight : 2.9 kilos.*

SONDE "GAMMA" MOYENNE DISTANCE — **SONDE "BETA" COURTE DISTANCE** — **SONDE "GAMMA" COURTE DISTANCE** — **SOURCE D'URANIUM**

MG - Longueur de câble : 20 m., étanche, prévue pour mesure de rayonnement GAMMA avec compteur 3 G 12 (LCT).

MG - Cable of 20 m lenght, watertight, designed for measuring Gamma radiations. Geiger tube : 3 G 12 (LCT).

CB - Longueur de câble : 1 m 20, étanche, prévue pour mesure de rayonnement BETA GAMMA avec compteur 5 B 17 (LCT).

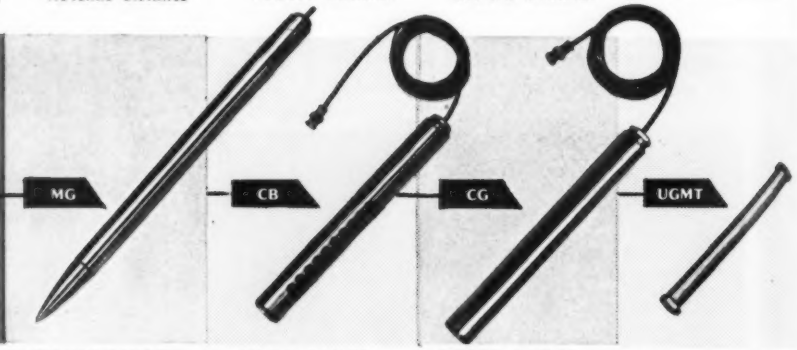
CB - Cable of 1.5 m lenght, watertight, designed for measuring Beta/Gamma radiations. Geiger tube : 5 B 17 (LCT).

CG - Longueur de câble : 1 m 20, étanche, prévue pour mesure de rayonnement GAMMA avec compteur GM 5 G 12 (LCT).

CG - Cable of 1.5 m lenght, watertight, designed for measuring Gamma radiations. Geiger tube : 5 G 12 (LCT)

UGMT - Source étalonnée pour contrôle de gammamètre et de sonde.

UGMT - For checking the correct calibration.



MEDIUM-RANGE "GAMMA" PROBE — *SHORT-RANGE "BETA" PROBE* — *SHORT-RANGE "GAMMA" PROBE* — *URANIUM SOURCE*

ACTISURF DOM 501

Détecteur de rayonnements destiné à la protection civile et militaire.

Gamme de sensibilités :
- 0/2 R/h — sur compteur interne
- 0/100 mR/h — sur compteur interne
- 0/3.000 c/s — sur compteur externe
- 0/300 c/s — sur compteur externe

Possibilité d'utiliser de nombreux accessoires tels que : sondes pour mesure de forte radioactivité, sondes pour mesure de faible activité en rayonnement GAMMA et BETA.

Mesure à distance au moyen d'adaptateur.

Poids en ordre de marche : 1.500 kg.

Très grande autonomie de fonctionnement.

Alimentation : 2 piles de 1,5 V.

Appareil étanche et tropicalisé.

Geiger counter, designed for the Civil Defense.

Ranges :
- *0/2 R/h — with internal counter*
- *0/100 mR/h — with internal counter*
- *0/3.000 c/s — with external counter*
- *0/300 c/s — with external counter*

Facilities for use of numerous accessories such as : probes for measuring of high radioactivities, probes for measurement of low radioactivities in GAMMA and BETA Radiations.

Remote measurements with impedance converter.

Long operation time without replacement of batteries.

Transistorized regulated supply.

Temperature ranges : — 15° C + 60° C.

Weight : 1,5 kg.

Dimensions : 180×110×150 m/m.

SOCIÉTÉ DE RECHERCHES

SRAT

& D'APPLICATIONS TECHNIQUES

41, RUE EMERIAU - PARIS 15e - TÉLÉPHONE VAU. 79-33

GAAA

GROUPEMENT
ATOMIQUE
ALSACIENNE
ATLANTIQUE

GAAA HAS BEEN ESTABLISHED FOR DESIGNING AND BUILDING NUCLEAR REACTORS, FOR SOLVING THE PROBLEMS RELATED TO THE CONTROL AND THE SAFETY OF THE REACTORS; THE HEAT EXCHANGES THROUGH GASSES AND LIQUIDS; THE CHARGING AND DISCHARGING; THE HANDLING OF IRRADIATED FUELS. TO COPE WITH THIS ACTIVITY, GAAA DISPOSES OF THE EXPERIENCE AND TECHNICAL RESOURCES BROUGHT IN BY THE TWO PARENT COMPANIES; FOR ITS MANUFACTURES, IT USES THE FACILITIES OF THESE TWO COMPANIES:

SOCIÉTÉ ALSACIENNE
DE CONSTRUCTIONS
MÉCANIQUES

CAPITAL : 41 090 000 NF
WORKS :
ARCUEIL
GRAFFENSTADEN
MULHOUSE
CLICHY

THE SACM IS GENERAL CONTRACTOR OF THE REACTORS G2 AND G3 AT MARCOULE

CHANTIERS
DE L'ATLANTIQUE
(PENHOET - LOIRE)

CAPITAL : 20 000 000 NF
WORKS :
SAINT-NAZAIRE
SAINT-DENIS

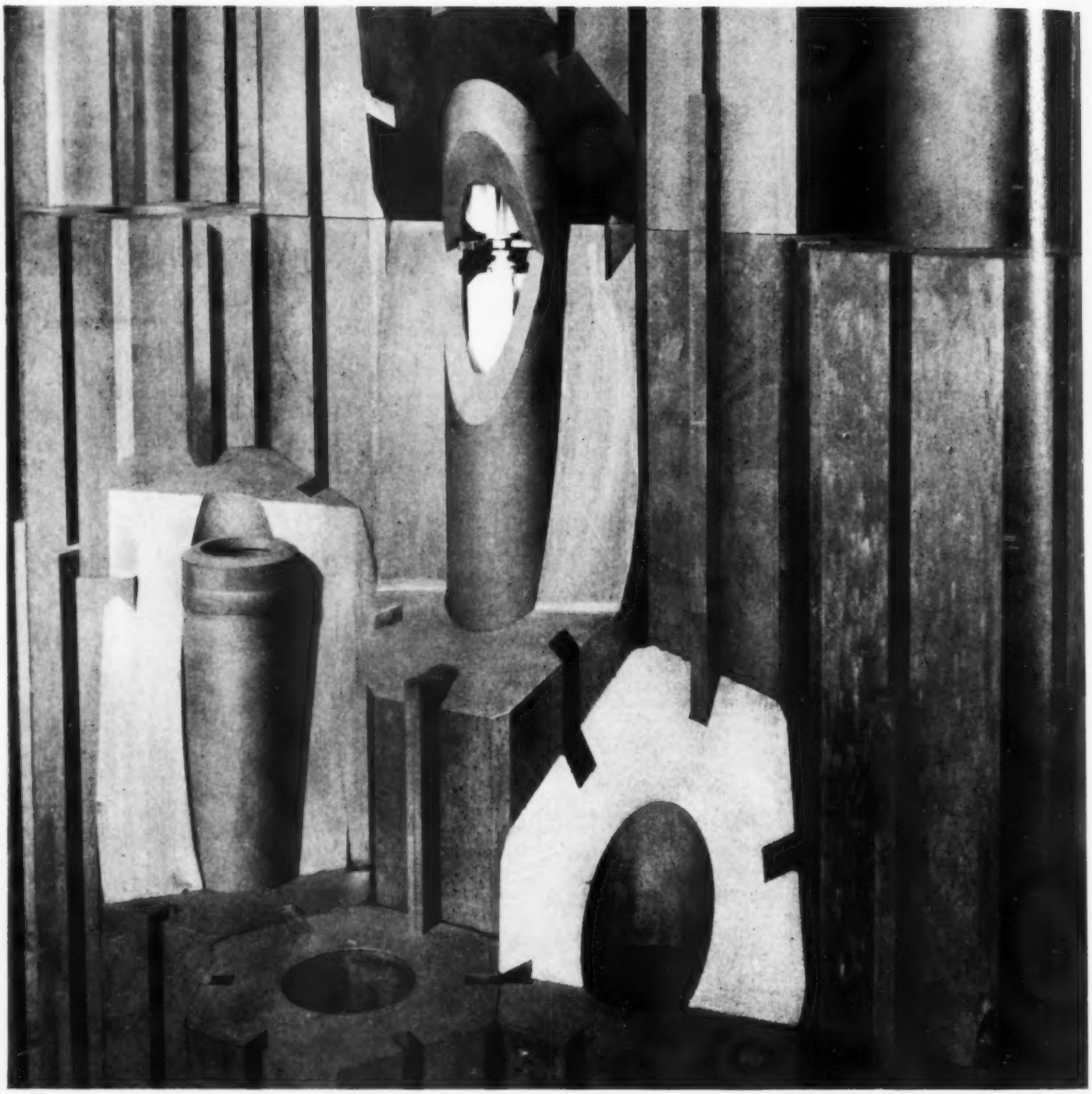
THE CHANTIERS DE L'ATLANTIQUE HAVE BEEN GENERAL CONTRACTOR OF THE REACTOR EL3 AT SACLAY

GROUPEMENT ATOMIQUE ALSACIENNE ATLANTIQUE

100 AV EDOUARD HERRIOT
LE PLESSIS-ROBINSON (SEINE)
CAPITAL : 4 000 000 NF

Impact

Tick **No 15** on reply card for further details



Section through graphite stack
Design patented by C.E.A., France

Graphite

Machined or unmachined

Moderator or reflector

Density 1,60 to 1,75 g/cm3
Cross-section 3,7 to 4,5 mb

PECHINEY Division Applications Atomiques

23 RUE BALZAC PARIS 8e

Tick No 16 on reply card for further details

STANDARD
FUNCTIONNAL
UNITS . . .

. . . master-key to nuclear instrumentation

Standard functional units are assembled in cabinets in order to be used as complete assemblies : scales for counting, amplitude selectors, ratemeters, etc...

REGISTER UNIT TYPE TND.1
Function :
counting (registering)
Dekatron divider

TIMER UNIT (SLOW RESPONSE)
TYPE TAL.2

Intended for automatic pre-set counting

VERY HIGH TENSION UNIT

RATEMETER TYPE TIS.1
supplies a tension or a current proportionnal to the number of counts received

TYPE THT.4
Supplies a very high stabilised tension for detectors, pre-amplifiers

ELA
L'ELECTRONIQUE APPLIQUEE
96/100, rue Maurice Arnoux • MONTROUGE • ALE 45-20, 83-20
25, rue du Docteur Finlay • PARIS 15e • TÉL. SÉGUR 14-75

Tick **No 17** on reply card for further details

LABINAL ÉLECTRONIQUE

présente

L'AMPLIFICATEUR MINIATURE A COURANT CONTINU ACM 103

ÉLECTRONIQUE NUCLÉAIRE

- Réponse linéaire ou logarithmique
- Grande stabilité
- Encombrement réduit (202 x 190 x 280)
- Appareil portable

CARACTÉRISTIQUES :

1° Avec préamplificateur linéaire
- Sensibilités de la tension de sortie + 50 mV, + 500 mV, + 5 V, + 50 V.
- Courant grille : inférieur à 5.10-14 A
- Dérive lente : inférieure à 1 mV/h.

2° Avec préamplificateur logarithmique
- Tension de sortie maximum : 6 V.
- Sensibilité en courant : 10-7 à 10-13 A.
- Réglage par courants étalons fournis par l'appareil à 10-8 et 10-11 A.

LABINAL ÉLECTRONIQUE fabrique également l'ensemble Chambre d'Ionisation-préamplificateur pour la détection des rayonnements B, V, X ou neutroniques.

AUTRES FABRICATIONS :
- Alimentations stabilisées et relais sans contact à transistors.
- Analyseurs différentiels à réseaux
- Tables traçantes numériques
- Ensembles d'automatisation.

Breveté S.G.D.G.

LABINAL ÉLECTRONIQUE
Département de
PRÉCISION MÉCANIQUE LABINAL
S. A. Capital 15.400.000 NF
126, Boulevard Victor-Hugo · SAINT-OUEN (Seine) ORN.09-04

Carbotrimètre®

for the dosing of low-energy β-emitters in liquid scintillators (^{3}H, ^{14}C, ^{35}S ^{45}C, etc...)

* *Minimum detectable energy level:* 10 keV
* *Detection efficiency:*
(a) 5% for tritium-treated water
(b) 10% for non-polar tritium-treated molecules
(c) 50% for carbon-14

* *Sensitivity:*
(a) detection limit for tritium: 2×10^{-10} curies in 15 min.
(b) detection limit for carbon-14: $1{\cdot}5 \times 10^{-11}$ curies in 15 min.

* *Random coincidence* (with scintillator) < 50 i.p.m. (within 3-60 V range)
* Measuring time presettable from 10 seconds to 16 hours
* Provision for analysis in two ranges sharing common threshold

Electronic circuit comprising:
—2 preamplifiers and 2 amplifiers (overall gain: 1,500 — rise time: 0·06 microsecond)
—1 coincidence selector (resolution time: 0·2 microsecond)
—1 2-band pulse-height selector (variable 3 to 100 V).

LE Belin

licence C.E.A.

LABORATOIRE INDUSTRIEL D'ELECTRONIQUE BELIN
296, Avenue Napoléon-Bonaparte - RUEIL-MALMAISON (S & O) FRANCE
Téléphone : 967-15-54 - Câbles : BELINUSINE-RUEIL

(R) *Registered Trade Mark*

HIGH QUALITY BOILERS

PACKAGE BOILER FOR COAL BURNING
from 1.000 lbs to 120.000 lbs
steam per hour
Pressure to 900 lbs/sq. inch
Superheating to 900° F

PACKAGE BOILER FOR FUEL OR GAS BURNING
from 1.000 lbs to 120.000 lbs
steam per hour
Pressure to 900 lbs/sq. inch
Superheating to 900° F

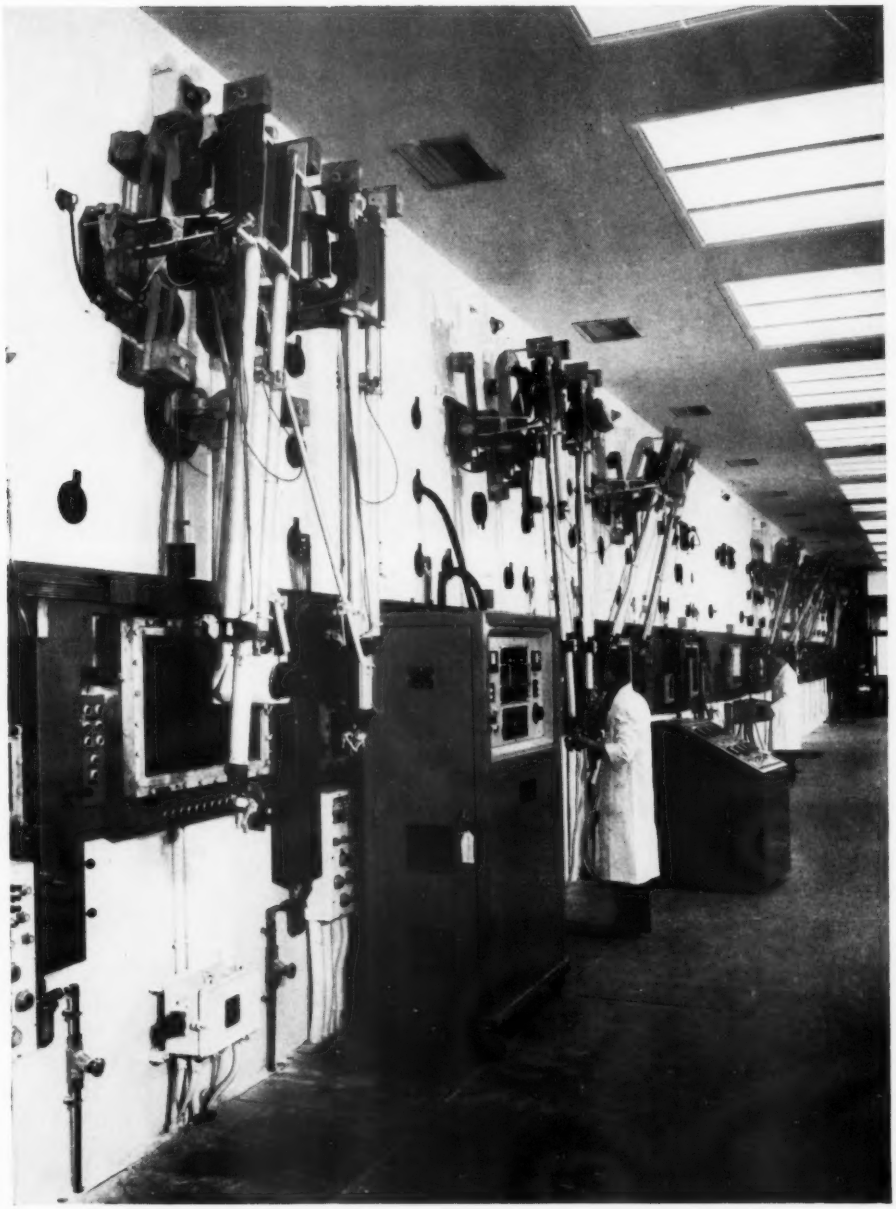
BOUËLLAT BOILERS

68, RUE POUCHET - PARIS 17E - TÉL. : MAR. 92-71

PUB. HUBERT BAILLE - PARIS

SAINT-GOBAIN

atome



SACLAY, FRANCE : 10-kilocuries hot cells at Saclay, France. These cells are equipped with radiation-shielding windows built by Saint-Gobain.

High-activity laboratories of this type, developed in cooperation with the French Atomic Energy Commission, are about to be supplied to foreign countries in Continental Europe.

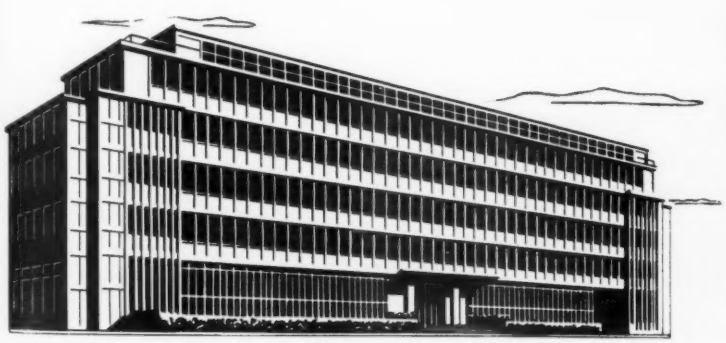
SERVICES NUCLÉARES SAINT-GOBAIN : 19, Ave. Georges Clémenceau, COURBEVOIE (Seine)

SIG
The S. I. C. N. supplies the Commissariat à l'Energie Atomique with the fuel elements of the power reactors G1, G2, G3 of the reactor EL2 ans of the nuclear power plants EDF-1 and EDF-2 of the French Electricity Authority.
SOCIÉTÉ
INDUSTRIELLE DE
COMBUSTIBLE
NUCLÉAIRE
69, RUE DE MONCEAU - PARIS-8ème
impact

The Compagnie Industrielle des Téléphones, a subsidiary of Compagnie Générale d'Electricité, has a division specializing on research and development in the field of data processing and transmission

- ***NUMERICAL SUPERVISION AND AUTOMATIC CONTROL EQUIPMENT FOR NUCLEAR PLANTS***
- ***INDUSTRIAL ELECTRONIC CONTROL***
- ***ELECTRONIC TELEMETERING AND REMOTE CONTROL***
- ***INDUSTRIAL DIGITAL COMPUTERS***

Compagnie Industrielle des Téléphones designs and manufactures equipments for atomic power stations: Chinon E d F 1 and E d F 2 - Marcoule G2 and G3



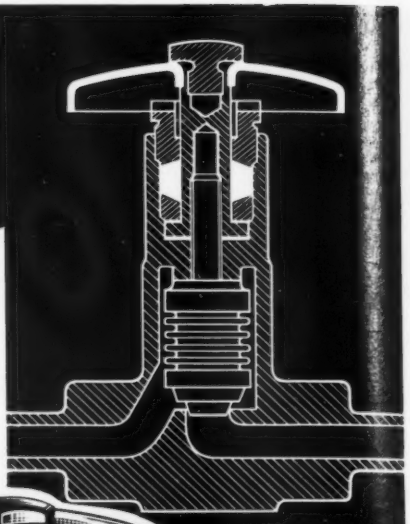
COMPAGNIE INDUSTRIELLE DES TÉLÉPHONES

DÉPARTEMENT TRANSMISSION

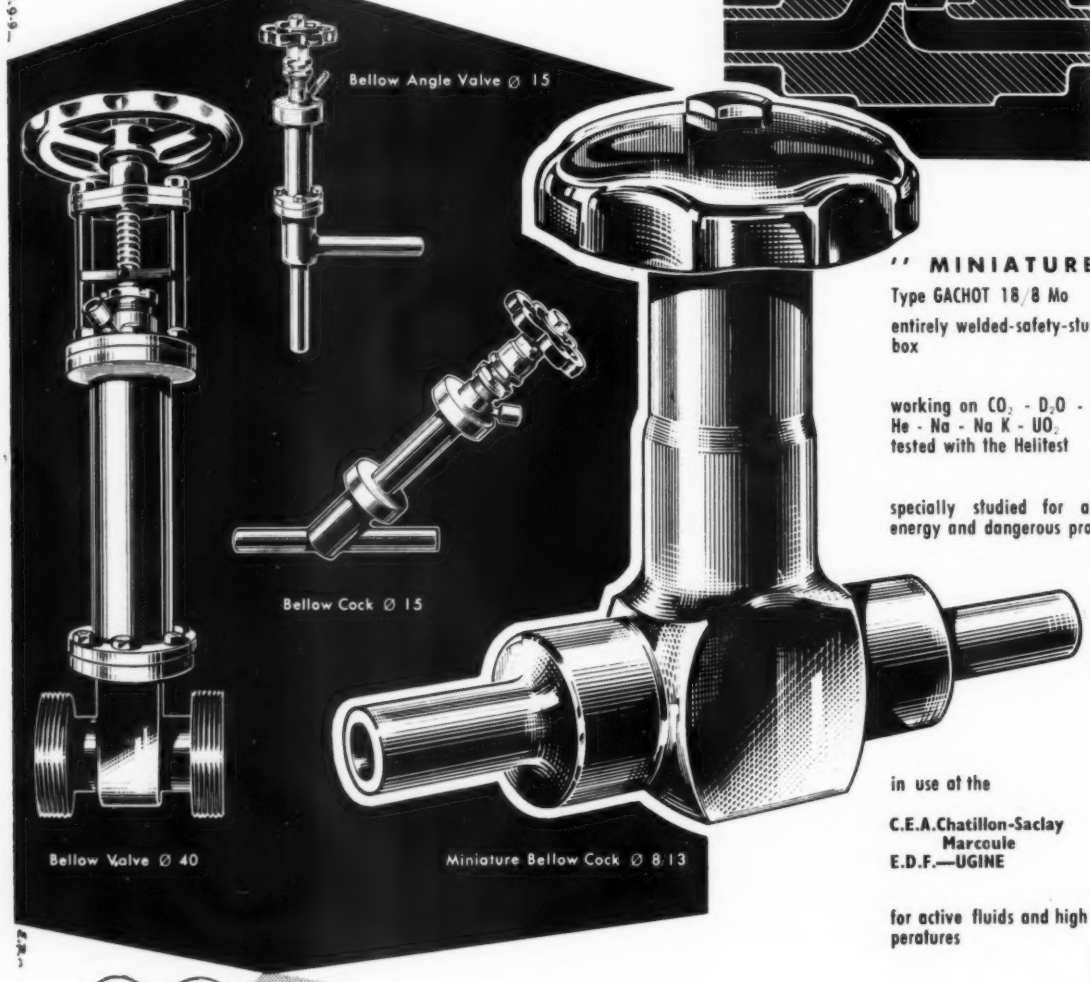
33, RUE ÉMERIAU – PARIS (15e)

VAU. 38-70

Bellow Cocks



Catalog TN 9-9



" MINIATURE "

Type GACHOT 18/8 Mo

entirely welded-safety-stuffing box

working on CO_2 - D_2O - UF_6 - He - Na - Na K - UO_2
tested with the Helitest

specially studied for atomic energy and dangerous products

in use at the

C.E.A. Chatillon-Saclay
Marcoule
E.D.F.—UGINE

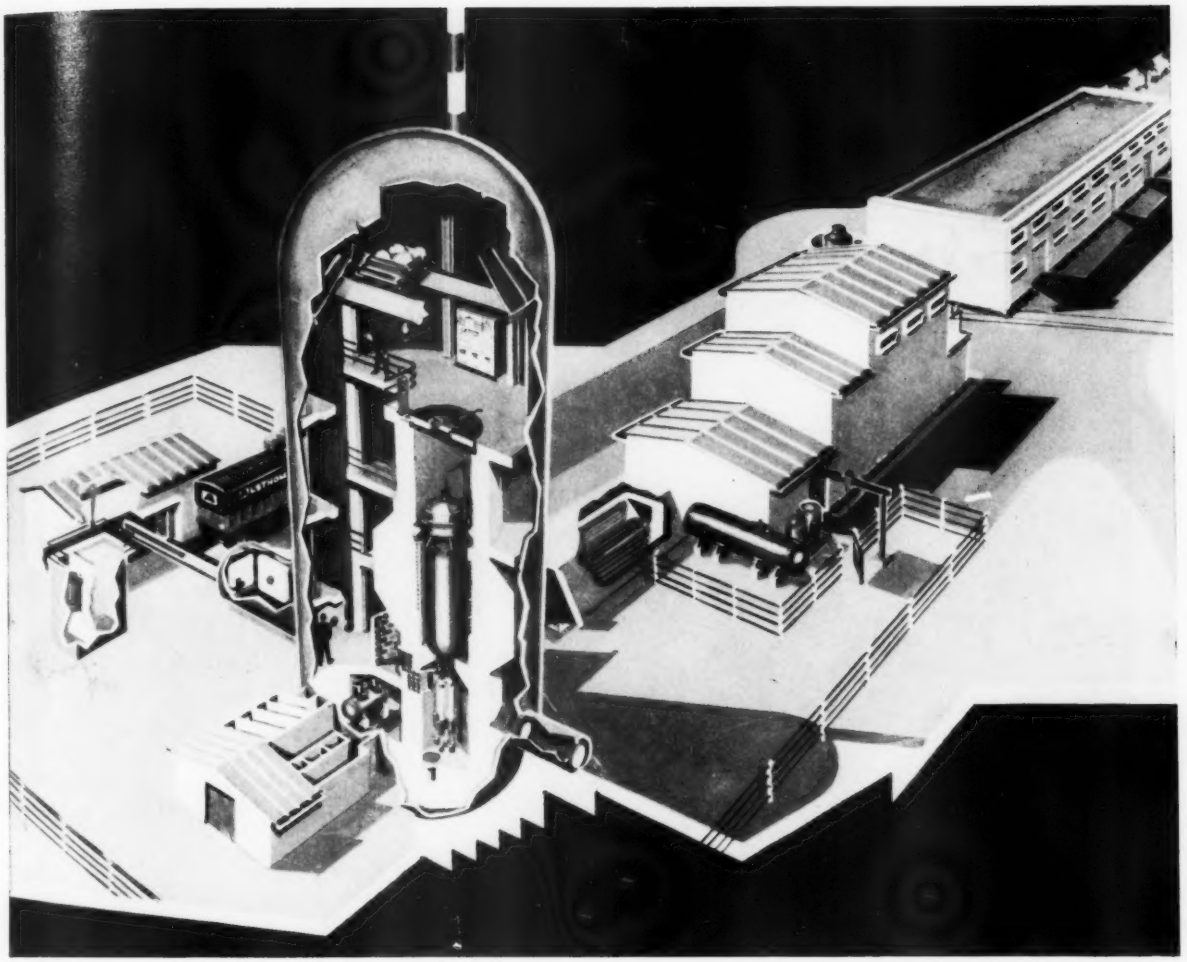
for active fluids and high temperatures

TN

TECHNIQUES NUCLÉAIRES

SOCIÉTÉ D'ÉTUDES ET DE RÉALISATIONS

82, RUE DE MONTIGNY - ARGENTEUIL (S.-&-O.) - **FRANCE** TÉL. 961-19-93



An Alsthom nuclear power plant project for overseas utility (Fort-Lamy) including a General Electric Co (U.S.A.) boiling water reactor.

ALSTHOM

has all the industrial and technical facilities convenient for the design and construction of complete nuclear power plants throughout the world.

38, avenue Kléber, Paris (8e) - **FRANCE**

Tick **No 25** on reply card for further details

PARTICLE ACCELERATORS

RAPY

1000 MeV - 20 mA

Such will be the performance of the **Electron Linear Accelerator** which the **COMPAGNIE GENERALE DE TELEGRAPHIE SANS FIL** is building at Orsay, near Paris, for the Laboratories of the Ecole Normale Supérieure (Faculty of Science).

C.S.F. has designed and built in its laboratories and works the accelerator wave-guides, the 20 MW amplifier klystrons, the power supply circuits and the modulators.

Compagnie générale de télégraphie Sans Fil

Société Anonyme au Capital de 40.608.900 Nouveaux Francs

Siège Social : 79, Bd HAUSSMANN - PARIS-8e - ANJ. 84-60

VALLOUREC

VALLINOX

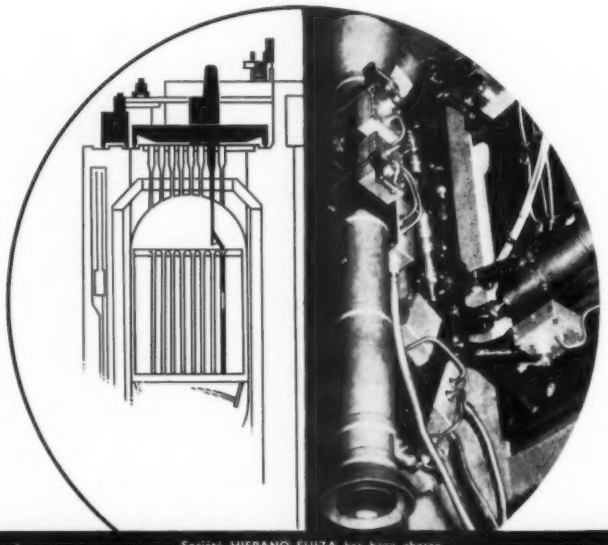
Deux grandes marques de tubes en aciers spéciaux et inoxydables pour l'industrie atomique

VALLOUREC

SOCIÉTÉ ANONYME AU CAPITAL DE 110 000 000 DE NOUVEAUX FRANCS

SIÈGE SOCIAL ET SERVICES COMMERCIAUX : 6, RUE DARU • PARIS (8e) • CAR. : 03-60, 05-00

Tick **No 28** on reply card for further details



NUCLEAR ENGINEERING
Charge and Discharge Machine
Hydraulic Equipment

REACTOR EQUIPMENT
Turbo-blowers · Compressors · Valves
Telemanipulators · Vacuum Pumps

REACTOR CONTROL
Control Rod and Control Rod Drive
Burst Slug Detection · Safety Circuits

RESEARCH and INSTRUMENTS
Fast Chopper for Intermediate Neutrons

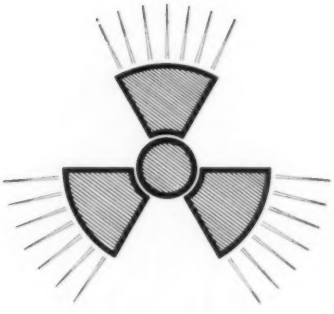
Société HISPANO SUIZA has been chosen by ELECTRICITE DE FRANCE to design and build the upper charge discharge assembly, for the E.D.F. 1 reactor at Chinon

DIVISION NUCLEAIRE
HISPANO SUIZA
BOIS-COLOMBES
SEINE - FRANCE

LEAD

ALL FORMS OF RADIATION PROTECTION

- CASTLES
- CONTAINERS
- COCKS
- BRICKS
- SHOT



- SHUTTERS
- DOORS
- POWDER
- TUBES
- SLABS

Licensed by the Commissariat à l'Energie Atomique, Paris

FONDERIE DE GENTILLY

56, rue Raymonde-Lefèvre GENTILLY (Seine) T. ALE 18,55

LABORATOIRES ET BANCS D'ESSAIS EXIGENT UN MATÉRIEL DE MESURE SANS FAIBLESSE

Equipez-vous CRC !

MULTIMÈTRE ÉLECTRONIQUE
VL 181
0,02 V à 30 kVcc, 0,1 à 30 kVca
1 à 10⁹ Ω

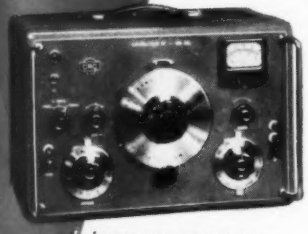
D'une construction extrêmement soignée

LES APPAREILS ÉLECTRONIQUES

CRC

SONT FAITS POUR DURER

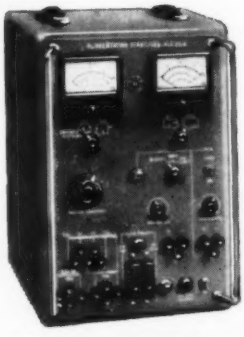
MILLIVOLTMÈTRE AMPLIFICATEUR
MV 153
1mV - 300 V (pour la déviation totale)



GÉNÉRATEUR BF GB 58
20 Hz - 40 kHz

EXTRAITS DU CATALOGUE

voici quelques exemples d'appareils pour l'équipement de base des Laboratoires, des Centres de Recherches et des Services d'Entretien, de Contrôle, de Fabrication, d'Exploitation, etc.



ALIMENTATION STABILISÉE ALS 82
0-400 V, 0-150 V - Chauffages

★ *NOTICE TECHNIQUE SUR DEMANDE*

OSCILLOGRAPHE HF
A FONCTIONS MULTIPLES
OC 560
Bande passante 0-30 MHz

AJAX N° 191

CRC

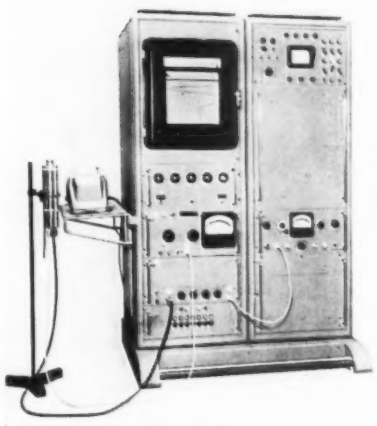
CONSTRUCTIONS RADIOÉLECTRIQUES ET ÉLECTRONIQUES DU CENTRE

19-21, RUE DAGUERRE, St-ÉTIENNE (LOIRE)
TÉLÉPH. : 32-39-77 (3 lignes groupées)

AGENCE DE PARIS : 70, Rue Saint-Blaise, PARIS 20e, Tél. : MÉN. 25-95

SOCIETE D'APPLICATIONS INDUSTRIELLES DE LA PHYSIQUE [S.A.I.P.]

38, RUE GABRIEL CRIE MALAKOFF. - SEINE TELE : ALE 87 20

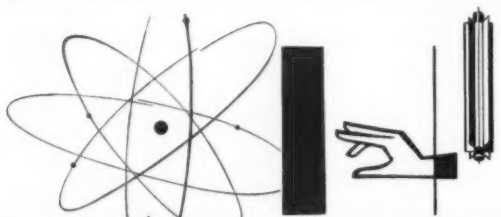


60-CHANNEL PULSE HEIGHT SELECTOR WITH MAGNETIC STORAGE "SA 60 M"

Number of channels.....60
Channel width .....1 V to 0·1 V
Channel width accuracy.....1% except channel 1
Variable threshold: permits analysis of.....160 channels
Resolution .....500 μs
Channel capacity.....65-535 pulses per channel
External gating signals: coincidence.....negative; 5 v–1 μs
Spectrum display: (*a*) CRT oscilloscope; (*b*) pen recorder; (*c*) output provisions for typewriter recording.

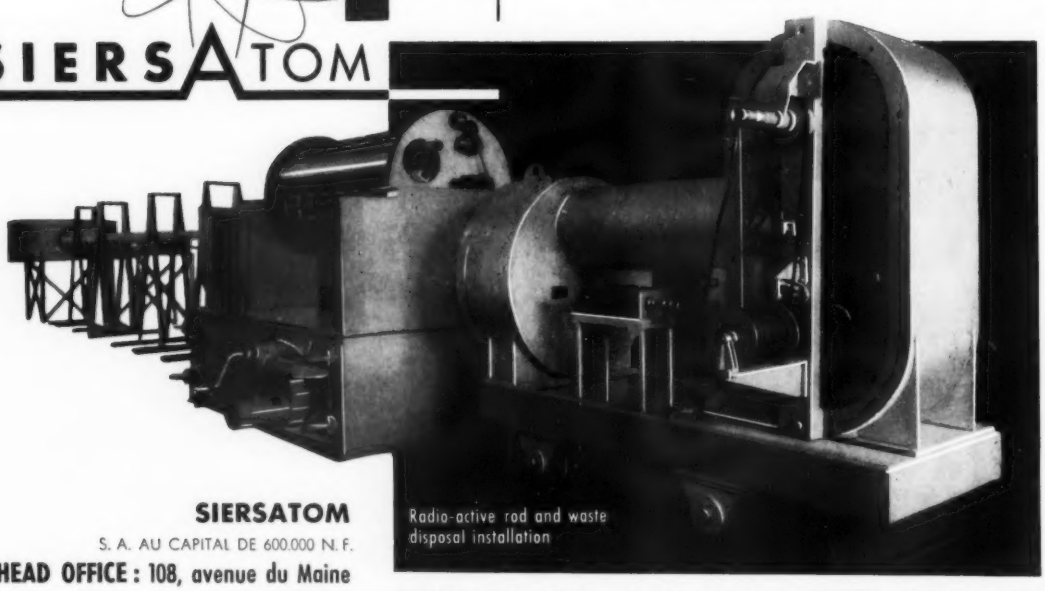
OTHER INSTRUMENTS

γ-ray spectrometers
Semi-liquid scintillation detectors for soft β-ray emitters
X-ray proportional counters
Flow counters
Fast neutron transistorised detectors
Level gauges
γ-ray gravitometers



- PROTECTION
- HANDLING, MANIPULATION
- CHEMICAL LABORATORY APPARATUS and INSTALLATIONS

SIERSATOM

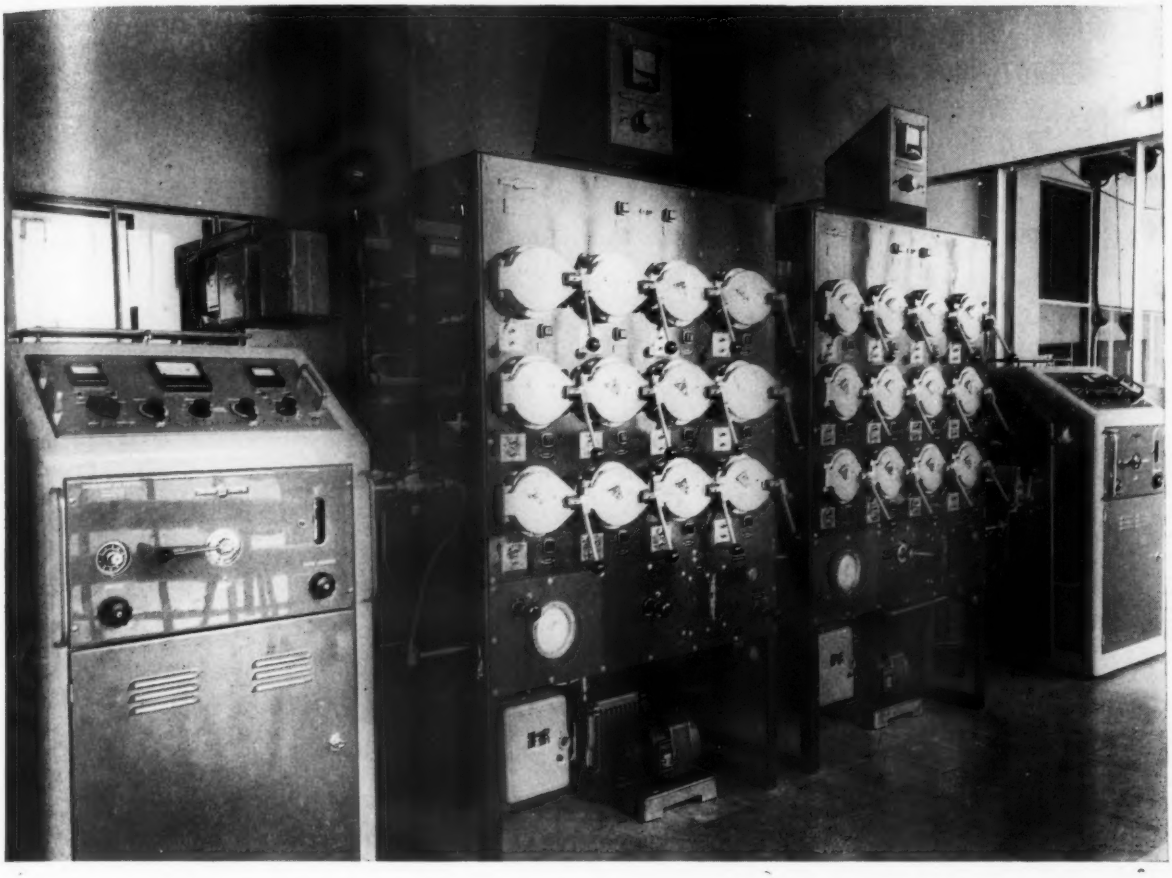


Radio-active rod and waste disposal installation

SIERSATOM
S. A. AU CAPITAL DE 600.000 N. F.
HEAD OFFICE : 108, avenue du Maine PARIS 14e

PHONE : SEGur 23-09 and SEGur 24-78 — CABLES : ROBISPE-PARIS

CFTH ACTIVITIES IN THE SPHERE OF NUCLEAR ENERGY



Sealing-test installation for the uranium slugs of reactors G2, G3, EDF 1 and EDF 2 (S.I.C.N., C.E.A., E.D.E.)

RESEARCH, DESIGN AND PRODUCTION ITEMS

Control and monitoring equipment for reactors;
Special servo-control and regulating mechanisms;
Direct-current amplifiers, period meters, transfer-meters;
Particle-accelerator RF power supply units;
Mass spectrometers for light elements;
Vacuum- and sealing-engineering applications;
Leak detectors and helium mass-spectrometers;
Sealing helium-seepage test;
Research pertaining to separation of stable isotopes;
Production of boron 10; Television monitoring-equipment;
Light independent side-band (I.S.B.) telecommunication equipment. Multiple-frequency portable sets for public safety and allied departments.
Television monitoring equipment

EQUIPMENT COMPLETED

Control and monitoring equipment for the EL3 and "Minerve" reactors, at Saclay and Fontenay-aux-Roses, respectively;

Transfer-meter for the EL3 reactor at Saclay;

RF units (tubes and cavities) for the linear accelerators of the 25 BeV synchrotrons of the C.E.R.N. in Switzerland and at Brookhaven (USA), respectively;

Amplifier-klystrons for high-output linear accelerators;

Sealing-test installation for the uranium slugs of reactors G2, G3, EDF1 and EDF2 (S.I.C.N. at Annecy, C.E.A. at Marcoule, EDF at Chinon);

Various television monitoring- and supervising-systems at Saclay, Marcoule, Fontenay-aux-Roses, Grenoble.

THOMSON CFTH HOUSTON

COMPAGNIE FRANCAISE THOMSON-HOUSTON — GROUPE ELECTRONIQUE — 173, BD HAUSSMANN — PARIS 8
Division Nucléaire - 1, rue des Mathurins - Bagneux (Seine) - ALE. 64-90

Tick **No 34** on reply card for further details

REMOTE CONTROL

PNEUMATIC MANIPULATORS

HEAVY MANIPULATORS

SPECIAL MANIPULATORS

SPECIAL REMOTE CONTROLLED AUTOMATIC MACHINES

E.R.T.N.

3, rue Victor Basch - ARCUEIL ALÉ. 31-77+ FRANCE

ANCIENS ÉTABLISSEMENTS

AUBERT ET DUVAL

A. R. J. DUVAL, SUCCESSEURS

41, RUE DE VILLIERS - NEUILLY SUR SEINE

TÉLÉPHONE : MAILLOT 88-30 - R. C. SEINE 56 B 1399

ADR. TÉL. : FALATLAS-PARIS - TELEX 20.655

ACIÉRIE DES ANCIZES

(PUY-DE-DOME)

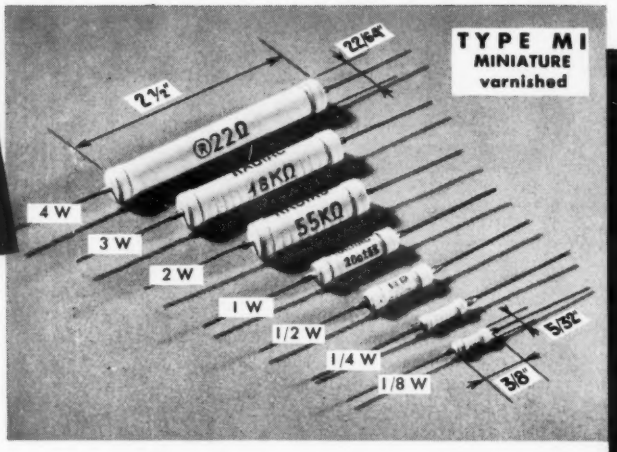
ACIERS ET ALLIAGES

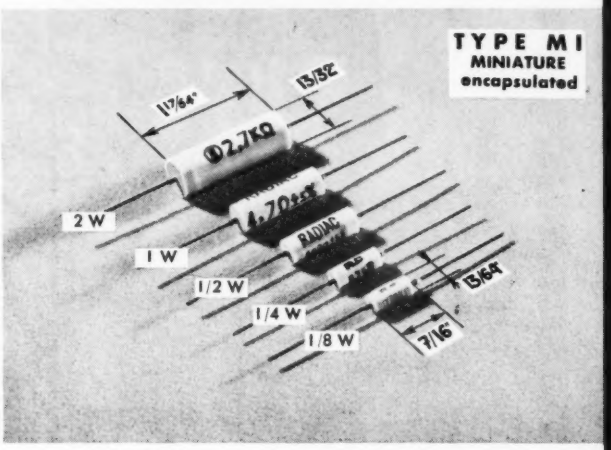
RÉPONDANT AUX EXIGENCES DE

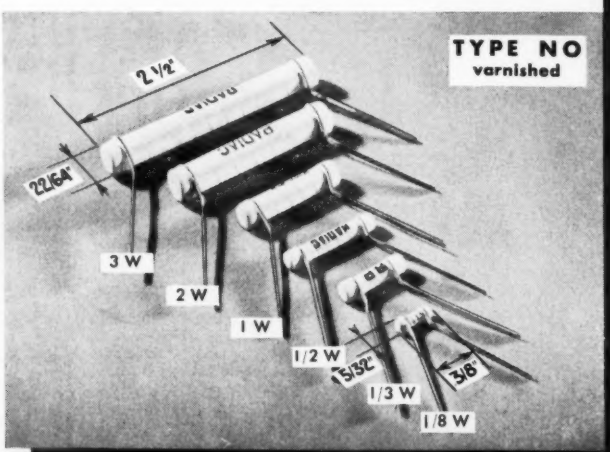
L'ÉNERGIE ATOMIQUE

RADIAC Resistors

A comprehensive range for all applications







3 STABILITY RATINGS

Standard : S.N class
High Stability : P.H.S class
Very High Stability : S.T.E class

8 TOLERANCE RATINGS

± 10% ± 5% ± 3% ± 2%
± 1% ± 0.5%
± 0.2% ± 0.1%

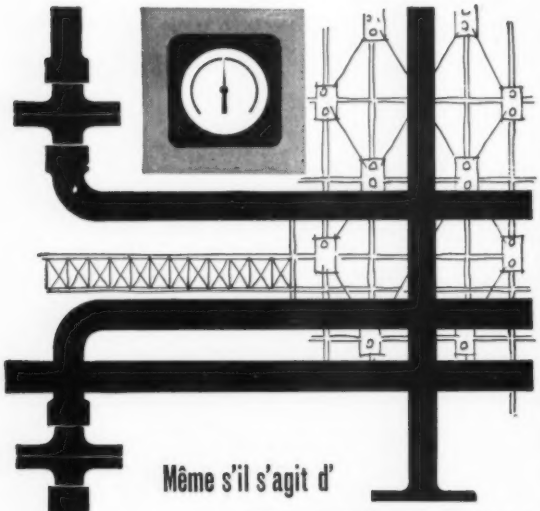
Technical literature sent on request

Sales Department
79, Rue du Faubourg Poissonnière
PARIS 9e (France) PRO. 39-51

Publi-Gead

AVAILABLE IN CUSTOM
OR PRODUCTION QUANTITIES

Tick **No 37** on reply card for further details



Même s'il s'agit d'

UF6

vos problèmes complexes de

Mesure
Contrôle **à distance**
Régulation

peuvent trouver une solution avec les

Capteurs

MANOMÉTRIQUES

SFIM

TYPES GA 12 et HA 12

à transmission par : potentiomètre ou transformateur différentiel

Puissances délivrées :
Sur potentiomètre : 1 W
Sur transfo différentiel : 2 mW
Autres fabrications : Manomètres pour mesure, contrôle et régulation à distance des pressions absolues ou différentielles de tous fluides, liquides ou gazeux.

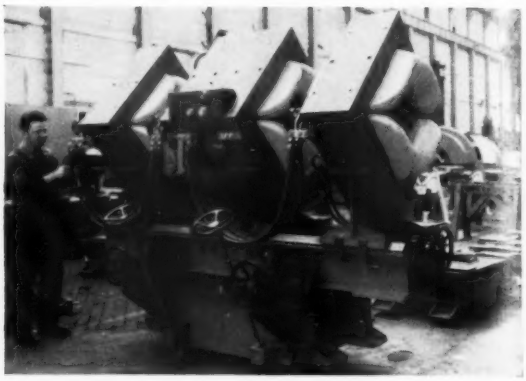
SFIM

AVENUE M. RAMOLFO - GARNIER
MASSY (S. et O.) - TÉLÉPH. 928-1090 +...

AM 05b

Tick **No 38** on reply card for further details

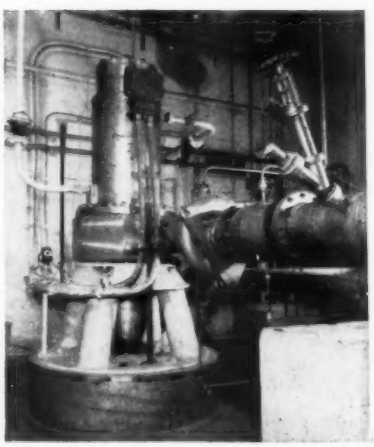
JEUMONT



SACLAY NUCLEAR RESEARCH STATION

Equipment for the "Saturne" proton synchrotron auxiliaries

6 × 100 kW power supply units
6 × 150 kW power supply units
2 × 300 kW power supply units
14 starter cabinets
6 quadrupoles — unit weight 8 tons
3 C-type electromagnets — unit weight 20 tons
2 H-type electromagnets — unit weight 36 tons



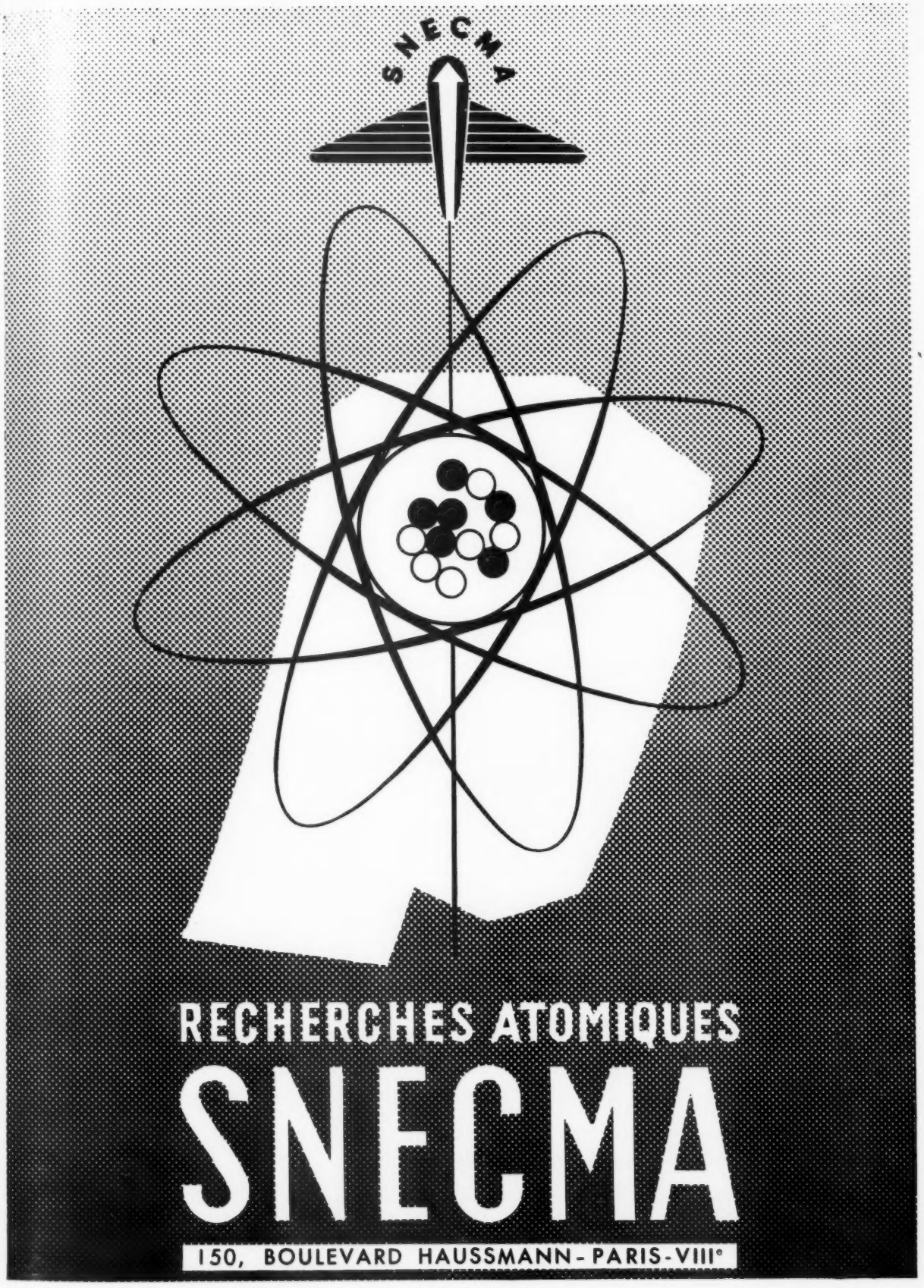
Electrically-operated pump circulating the heavy water in reactor No. 3 (EL3)

Motor: 190 h.p. at 1500 r.p.m. driving a Rateau pump.

The Jeumont Company is licenced by Westinghouse under the terms of an agreement between the WESTINGHOUSE ELECTRIC CORPORATION and the French FRAMATOME Company.

JEUMONT

5, Place de Rio de Janeiro, Paris 8e.


SNECMA
RECHERCHES ATOMIQUES
SNECMA
150, BOULEVARD HAUSSMANN - PARIS-VIII°

Tick **No 40** on reply card for further details

PROGIL

SOCIETE ANONYME AU CAPITAL
DE 40 MILLIONS DE NF

INDUSTRIAL CHEMICALS

HYDROGEN

**CAUSTIC SODA—
SOLUTIONS AND FLAKES**

DIPHENYL—POLYPHENYLS

HYDROGENATED POLYPHENYLS

**ORTHOPHOSPHATES—
POLYPHOSPHATES**

CHLORINATED SOLVENTS

CARBON TETRACHLORIDE

HYDROCARBONS

DODECANE

SPECIAL LUBRICANTS

**"GILOTHERM"
HEAT TRANSFER FLUIDS**

For brochure write to :—

PROGIL

EXPORT DEPARTMENT

79, rue de Miromesnil,

PARIS 8e — LAB 91-60

Tick **No 41** on reply card for further details

Turbine generator for nuclear reactor "G2" (first French nuclear plant), for which Société RATEAU supplied also the turbine and motor-driven blowers, and the isolating valves.

—Steam and Gas Turbines,
—Compressors and Blowers,
—Fans and Pumps,
—Industrial Valves.

SOCIÉTÉ RATEAU
FRANCE

SPECIAL SUPPLIES FOR NUCLEAR INDUSTRY

—Cooling, energy generating, and ventilating circuits,
—Turbine driven and motor driven blowers for air, CO_2, etc.,
—Gas-sealed compressors,
—Fans, coolers and filters,
—Low-pressure steam turbine and auxiliary supplies for nuclear plants,
—Canned motor pumps,
—Special supplies for the uranium 235 separation plant (compressors, valves, etc.),
—Special valves.

PNEUTOMATION

for accurate control

No matter how complicated the sequence of industrial processes, Lang Pneumatic Control equipment eliminates human error, and operates continuously to predetermined standards of accuracy.

Every item of Lang Pneumatic Control equipment has been proved over and over again in tests and in actual use. Design, workmanship, and choice of materials ensure long service, freedom from trouble . . . and consistent accuracy.

PNEUTOMATION
CANNOT FORGET

PNEUTOMATION—
ENERGY UNDER
CONTROL

Mr. Squinch says:
Don't monkey around with production problems:
consult Lang Pneumatic.

Write to:

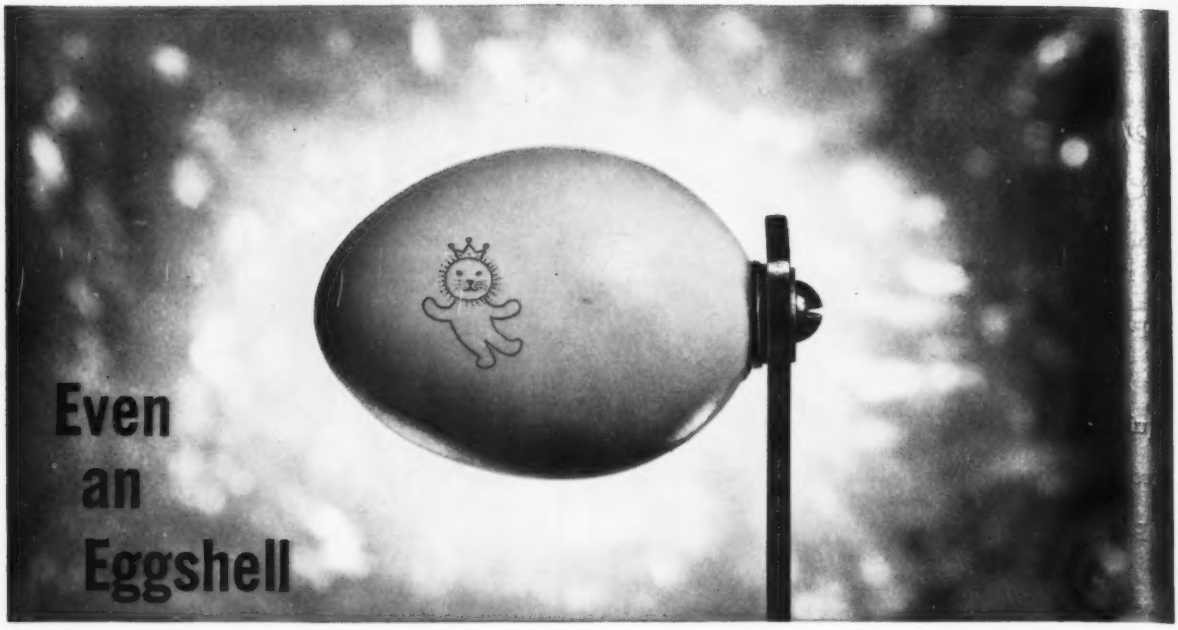
Lang Pneumatic Ltd
(ASSOCIATED WITH DESOUTTER BROTHERS (HOLDINGS) LTD)

OWEN ROAD · WOLVERHAMPTON

Tel: Wolverhampton 25221 2 3 4
Telex No. 33153

P3642

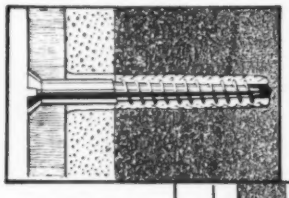
Tick **No 42** on reply card for further details



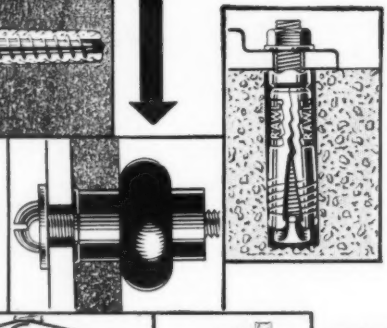
can be Screw-fixed with a RAWLPLUG FIXING DEVICE!

If you live to a hundred, you are unlikely to want to do much screw-fixing of eggshells! Yet this feat—possible only with a Rawlplug Fixing Device (a Rawlnut)—does serve to highlight the astonishing effectiveness of these Devices in making 'difficult' and even 'impossible' fixings simple and straightforward. Whatever the screw or bolt fixing job, you'll save time, money and temper by using the appropriate Rawlplug Fixing Device.

RAWLPLUGS
The famous Rawlplug makes firm screw fixings in masonry in a mere fraction of the time taken by any other method. For all screw sizes up to ¾" diam. coach screws.

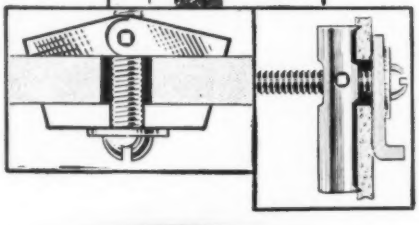


RAWLNUTS
The amazing Rawlnut forms its own 'rivet head' behind the material when screwed up from the front. Shakeproof and waterproof, it has many valuable uses in both building and manufacture.



RAWLBOLTS
For light or heavy bolting jobs. A dry fixing of enormous strength—no cold chiselling, no waiting for cement to harden. In all bolt diameters up to 1".

SPRING TOGGLES
For making firm fixings to such thin and structurally weak materials as plasterboard, ceilings, etc. The wings of the device spring apart behind the material and spread the load over a wide area.



GRAVITY TOGGLES
Passed through a hole in hollow material, the long member falls into a vertical position by gravity, and is then drawn against the back of the material by screwing from the front.

IMPOSSIBLE FIXINGS ARE EASY WITH

RAWLPLUG WALL PLUGS

FIXING DEVICES *For Speed and Strength!*

The World's largest manufacturers of fixing devices

THE RAWLPLUG COMPANY LTD., CROMWELL RD., LONDON S.W.7

B669

the Atom

AT HOME AND ABROAD—ON LAND AND SEA

Simon-Carves, in association with The General Electric Company of England, are building the first commercial nuclear power station in Scotland and the first in Japan —the latter the first in the world to be designed to withstand earthquakes. They are also developing nuclear power plant for marine propulsion. The combined experience and resources of these two great companies in research, construction and contracting are playing a leading part in keeping British nuclear engineering in the forefront of the world.

Simon-Carves Ltd

SIMON ENGINEERING GROUP

NUCLEAR POWER DIVISION / Cheadle Heath Stockport

IN ASSOCIATION WITH THE GENERAL ELECTRIC CO LTD OF ENGLAND

Tick **No 44** on reply card for further details

Greater safety for hands

With new Shell Dromus Oils

Most modern soluble cutting oils contain phenolic compounds used as coupling agents between the oil and the emulsifier, for better blending and easier mixing. These phenolic compounds can cause skin irritation, especially where modern high-speed machines are used and the emulsion can concentrate, through the evaporation of water, above the safety level.

Shell research chemists have been working on this problem, which has been causing some concern to Management. After considerable research, Shell Dromus Oils have been reformulated and these new cutting oils now produce bland emulsions, which considerably reduce the risk of skin trouble to operators.

The real difficulty was to find a new coupling agent to replace the phenolic compounds, and Shell finally used what their chemists know as a higher fatty alcohol complex. This solved one problem, but presented another. The new coupling agent was volatile at the high temperatures normally used in blending processes. Further research found a solution to this problem by designing and installing new plant.

The new Dromus Oils are every bit as efficient as before and cost no more. They put Management in the welcome position of being able to minimise working hazards at no extra cost. And machine men need no longer be so worried about skin troubles.

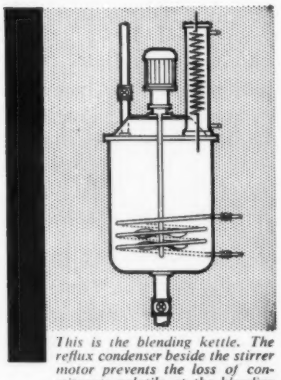
The moral of the story is that Shell research is supremely applicational. The centre at Thornton is always ready to work with even the most specialised sectors of industry to produce the right oil for the job. If you and your organization have any major lubricating problems, it pays to get in touch with your local supplier of Shell Industrial Lubricants.

The Research Story

Shell chemists in the U.K., in Holland and in the U.S.A., prepared and examined hundreds of experimental soluble oils, and established that certain combinations of fatty alcohols could be used in place of phenolic compounds with no loss of efficiency. They set to work to discover the best combination and developed a higher fatty alcohol complex which fitted exactly. Then they realised that to blend this new coupling agent into soluble oils would require special plant and new blending techniques.

Exhaustive testing of blend stability, emulsion stability, anti-corrosion and machining properties led to selection of the most promising blends. A pilot plant was set up to produce batches of these for use in field trials.

This field testing and final development proceeded for two years whilst production plants were erected at points so chosen as to give the most economical and rapid delivery throughout the United Kingdom.



This is the blending kettle. The reflux condenser beside the stirrer motor prevents the loss of constituents volatile at the blending temperature.

NEW SHELL DROMUS SOLUBLE CUTTING OILS

another proof of Shell leadership in lubrication

Tick **No 46** on reply card for further details

Fused and Ground UO_2 Selected by Hanford for Plutonium Recycle Test Reactor

SPENCER stoichiometric fused and ground uranium dioxide was chosen for the compacted fuel rods of the Hanford Plutonium Recycle Test Reactor.

Compaction densities in the tube have been announced by Hanford as 91% to 92% of theoretical.

Properties of this material are as follows:

1. Uranium dioxide composition: $UO_{2.005}$

2. Particle density: greater than 99.9% of theoretical density, as measured by both X-ray diffraction and standard immersion techniques.

3. Particle size: normally offered in —20 mesh particle size. Special orders may be made in any particle size distribution desired.

4. Typical spectrographic analysis (—20 mesh material):

Element	ppm	Element	ppm
Silver	0.3	Magnesium	30
Aluminum	25	Manganese	20
Boron	0.5	Molybdenum	2
Cadmium	0.1	Nickel	10
Carbon	50	Phosphorus	10
Chromium	10	Lead	5
Copper	5	Silicon	50
Iron	75	Tin	1

5. Availability: laboratory quantities or production quantities. Supplied either from Spencer's original high enrichment plant or from Spencer's new 100,000-pound low enrichment plant.

Also available from Spencer Chemical Company: (1) Ceramic grade uranium dioxide that will sinter to a fired density of 10.5 grams per cc. This material made by continuous process and especially tailored to meet the specifications for your production line. (2) Cermet grade uranium dioxide that has a particle density of greater than 99.9% of theoretical density. This material made from pure crystals of fused UO_2.

For complete details, contact Spencer Chemical Company, Nuclear Fuels Department, Dwight Building, Kansas City 5, Missouri.

SPENCER URANIUM DIOXIDE

Produced by

SPENCER®

Spencer Chemical Company

America's Growing Name In Chemicals

General Offices: Dwight Building, Kansas City 5, Missouri, U.S.A.

Reliable Honeywell instruments stand guard against waste and danger . . . in the central control room at Dounreay and in the containment sphere where the reactor itself is housed.

£20,000,000 protected at Dounreay . . .

Honeywell is Instrumental

Honeywell

First in Control

WRITE OR SEND THE COUPON TODAY for more information to Honeywell Controls Ltd, Ruislip Road East, Greenford, Middlesex. Telephone: Waxlow 2333

Please send items ticked	N.P.
Brochure S.A.D.1. reviewing the entire range of Honeywell industrial instrumentation	☐
Specification Sheet 164 (Strip Chart Recorders)	☐
Specification Sheet 160 (Circular Chart Recorders)	☐

NAME _____

APPOINTMENT _____

ADDRESS _____

_____

Branches in the principal cities of the U.K. and throughout the world.

A massive investment of supreme national importance, the reactor station at Dounreay is monitored by Honeywell instruments in three vital ways:

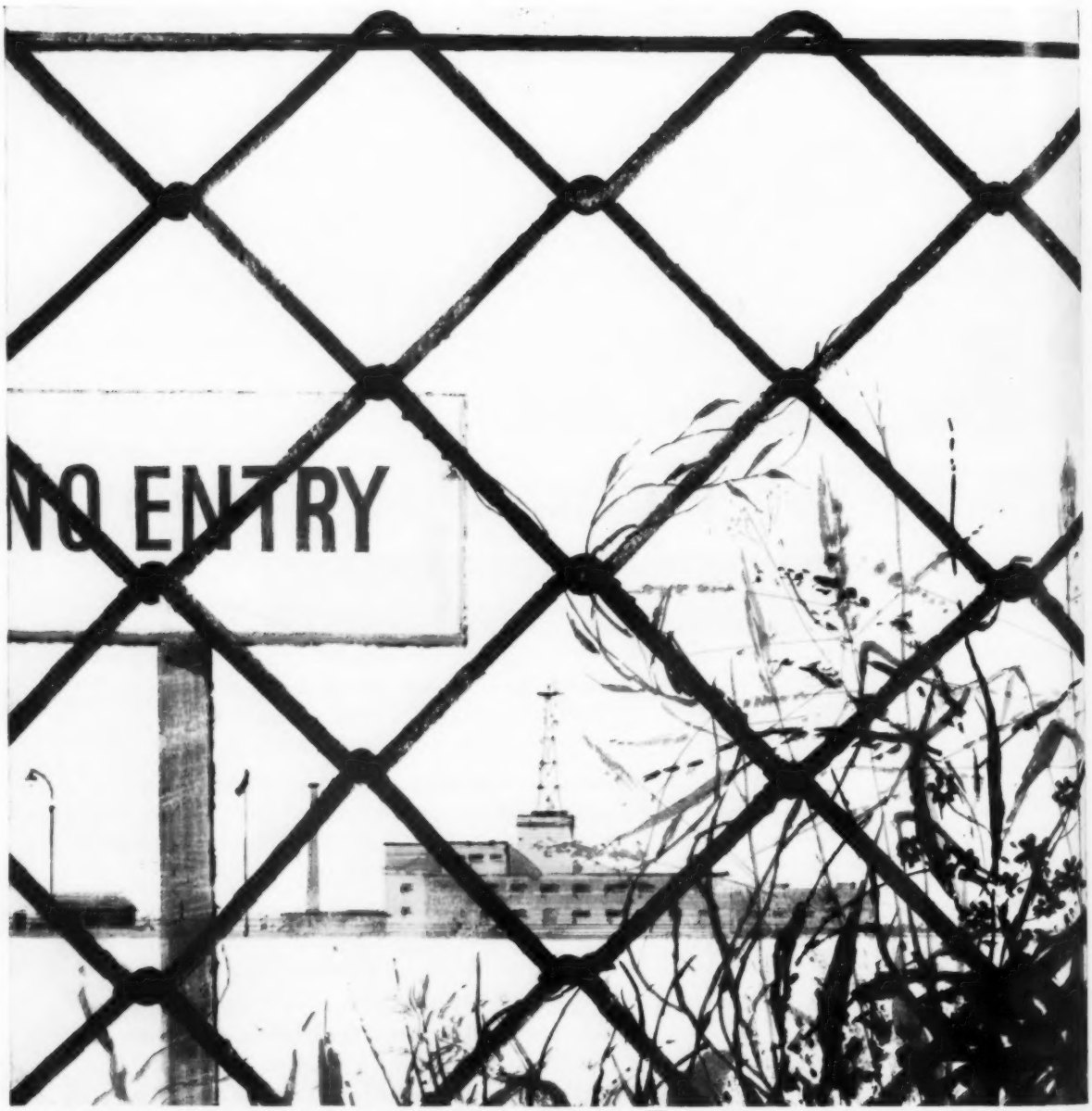
Keeping the reactor safe ElectroniK Recorders monitor reactor variables — critical temperatures . . . neutron flux . . . thermal power. Honeywell Micro Switches close emergency shut-down circuits at danger point.

Keeping it cool Pressure and Flow Meters control sea water cooling . . . relate seabound heat flow to turbine demands . . . prevent water returning to the steam heater at too high a temperature.

Keeping it efficient ElectroniK Recorders receive signals from ion chambers within the breeder blanket . . . depict events at the reactor core . . . enable the nuclear reaction rate to be adjusted to current demands.

Tick **No 48** on reply card for further details

Lead shielding of a complicated nature is being
successfully produced to Harwell design by
R. E. Roberts & Son Limited, Bolton,
for the U.K.A.E.A., Risley, and for private companies engaged
in the development of nuclear power.



R. E. ROBERTS & SON LTD., WINDLEY STREET, BOLTON, LANCASHIRE FC A MEMBER OF THE FIRTH CLEVELAND GROUP

CRC 7R

Comprehensive service to meet your radiography and radiation source needs.

The Budd Company maintains one of the largest commercial facilities to meet practically every industrial radiation requirement. Budd is fully equipped to supply many types of radiation source, fabricated in any size and configuration . . . containing several radioisotopes available from a number of reactor stations. Furthermore, the engineering and scientific staff at Budd can supply irradiation engineering consultation and complete irradiation facilities.

Consult The Budd Company about your radiation requirements. Contact The Budd Company representative at 49 Avenue Georges V, Paris 8e, France.

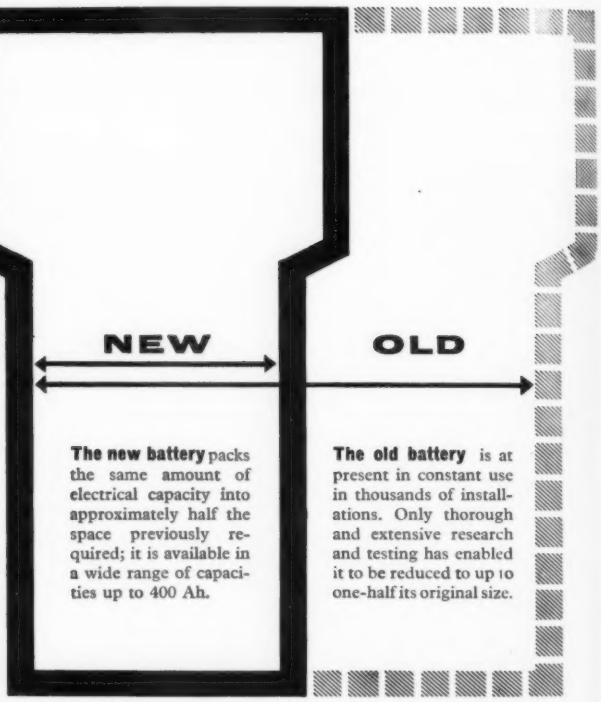
INTERNATIONAL Budd DIVISION

Tick No 50 on reply card for further details

BATTERY SPACE REDUCED BY HALF

WITH THE NEW TUDOR HIGH PERFORMANCE STATIONARY CELL

Savings of up to 50% in the space required for a stationary battery are made with the introduction of a new Tudor cell. A high performance sealed cell with Planté positive plates and pasted grid negative plates, separated by ribbed diaphragms of microporous Porvic, it is specially designed for trickle-charge operation.
It is therefore the ideal cell for all stand-by applications, including emergency lighting in hospitals, cinemas, theatres and public buildings of all kinds, and auxiliary duties in both nuclear and conventional power stations.
The design of the cell results in a lower internal resistance and therefore provides a very much improved high rate performance, making it eminently suitable for switch-operating duties where high rates of discharge are involved.
With the great reduction of space required, and the renowned reliability and long life of its predecessors, this new Tudor high performance cell marks a great step forward in stationary battery design.

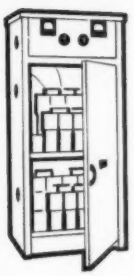


The new battery packs the same amount of electrical capacity into approximately half the space previously required; it is available in a wide range of capacities up to 400 Ah.

The old battery is at present in constant use in thousands of installations. Only thorough and extensive research and testing has enabled it to be reduced to up to one-half its original size.

THE IMPROVED SAFETYLYTE EMERGENCY LIGHTING EQUIPMENT

Tudor Safetylyte equipments are now being fitted with the new stationary cell. Charge and control cubicles are of improved design – the larger equipments being of folded sheet steel, and the smaller specially constructed for wall-mounting, employing automatic mercury relay in place of a contactor.



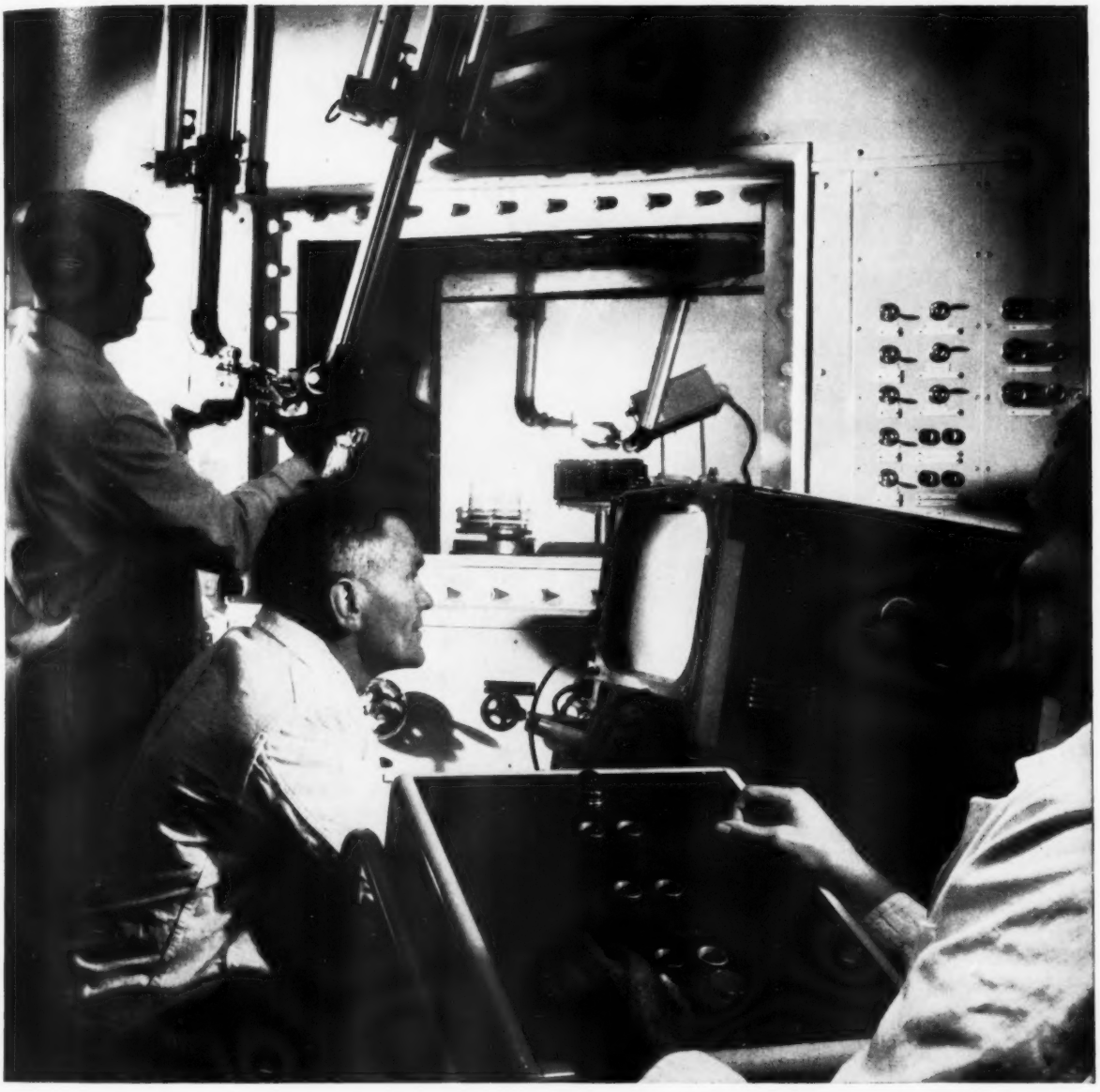
THE NEW SWITCH-TRIPPING EQUIPMENT

Tudor switch-tripping units will in future be fitted with the new cell. The cubicles have also been redesigned, and are available in folded sheet steel or wooden cabinet construction. The charger can now be used for both trickle and quick charging.

T 173A

Tudor TUDOR BATTERIES

THE D.P. BATTERY CO. LTD, MAKERS OF KATHANODE AND TUDOR BATTERIES, BAKEWELL, DERBYSHIRE. TEL BAKEWELL 581-5

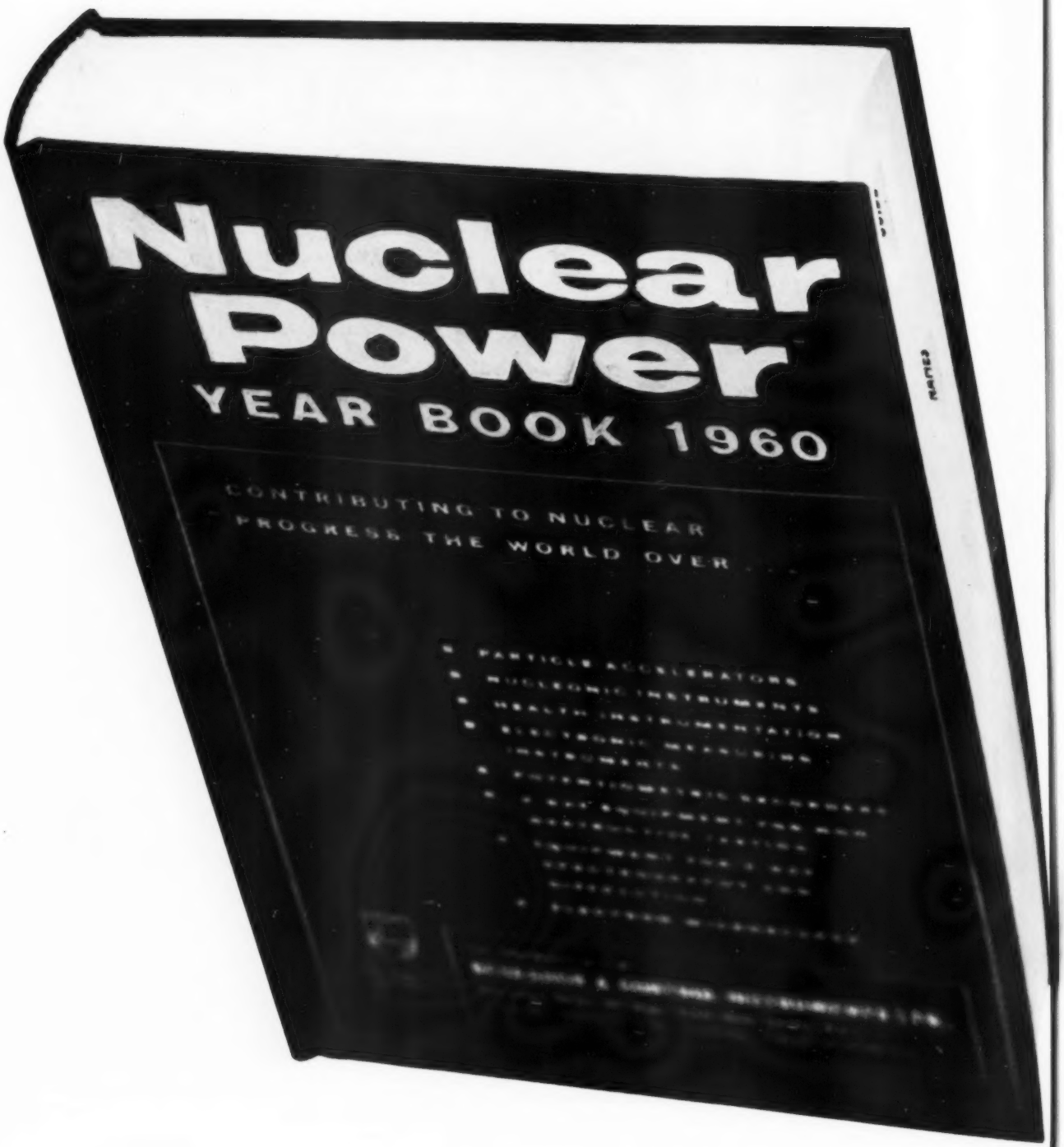


Pye at Dounreay

The Pye Instrument Group has supplied all the equipment to the U.K. Atomic Energy Authority for the irradiated fuel element laboratory at Dounreay. In addition to supplying equipment, Pye Ltd. acted as consultants and designers on all matters in that laboratory relating to instrumentation and remote handling. The illustration above shows manipulators working in conjunction with a television camera to handle and measure a sample from the fast reactor.

The Pye Instrument Group consists of: Pye Atomics Division; Pye Industrial Television Division; Faraday Electronic Instruments Ltd.; Labgear Ltd.; W. G. Pye & Co. Ltd.; Pye Telecommunications Ltd.; Unicam Instruments Ltd.; W. Bryan Savage Ltd.; W. Watson & Sons Ltd.

Tick **No 52** on reply card for further details


Nuclear
Power
YEAR BOOK 1960
CONTRIBUTING TO NUCLEAR
PROGRESS THE WORLD OVER

THE 1960 NUCLEAR POWER YEAR BOOK & BUYERS' GUIDE

NOW IN ITS 3rd EDITION

the Nuclear Power Year Book and Buyers' Guide is the only comprehensive publication of its kind in the world

CONTENTS

1 1960 Review
An uptodate critical review of the British nuclear power scene, details of the British nuclear contracting groups and the electricity generating authorities, data on British reactors, map of nuclear energy establishments and power stations.

2 World Authorities
The history, organization and plans of all national atomic energy authorities and international bodies. Addresses of establishments and names of leading officials.

3 Technical Data
Articles and tables on reactor physics, instrumentation and special metallurgy.

4 Isotope Section
A 60-page table giving the principal properties of all known nuclides including indication of sources of supply. Precautions to be taken in the use of radioactive substances.

5 Company Addresses
Titles, addresses, directors, home and overseas branches of nearly 2000 British firms supplying the nuclear energy industry.

6 Buyers' Guide
Firm's products classified under 750 different headings.

7 Trade Names
Products identified under registered titles.

8 Who's Who
Biographical details of over 600 leading men in British nuclear energy.

Revised from cover to cover the 3rd edition of NUCLEAR POWER YEAR BOOK and BUYERS' GUIDE is essential for management, designers, operators and research workers in the field of atomic energy.

Order your copy now—price £2.12.6 (post free)

ROWSE MUIR PUBLICATIONS, 3 PERCY ST., LONDON, W.1, ENGLAND

Over a Ton of Aluminium Alloy spun to 10 ft. i/d x $1\frac{5}{8}$"

One of a number produced for pressure vessels to hold liquid air, this 10 ft. aluminium end was spun by Harveys on the Rotarpress. The 12 ft. flat discs needed for spinning these ends, which are believed to be the largest spun aluminium ends produced in this country, were formed by butt-welding two plates of aluminium alloy together.

The Rotarpress is one of the large-capacity units in Harveys Heavy Fabrication Department. It produces ends up to 15 ft. diameter and is adaptable over a wide range of knuckle radii and depths.

The contours of semi-ellipsoidal ends produced by the spinning process enable plate thickness to be reduced, and in most cases tool costs are eliminated. Enquiries are invited for ends only or for complete

FABRICATION OF PRESSURE VESSELS.

HARVEY

G. A. HARVEY & CO. (LONDON) LTD.

Woolwich Road, London, S.E.7. GREenwich 3232 (22 lines)

Other Harvey facilities: FABRICATIONS UP TO 120 TONS IN ONE PIECE · HEAVY MACHINING AND FITTING · HEAT TREATMENT AND RADIOGRAPHY · STEEL PLATE AND SHEET METALWORK · PERFORATED METALS · WOVEN WIRE · WIREWORK HP/7

THESE WERE THE PROBLEMS..

1. to expose every little imperfection

2. to keep pace with production

THE INSPECTION DEPARTMENT at Powell Duffryn Carbon Products Ltd. had two problems.

Powell Duffryn were supplying the graphite struts which form part of the fuel-element assembly at Berkeley. These struts were of square section, with one end slightly rebated to accept a zirconium alloy cross-member, and drilled to contain a metal pin joining the cross-member to the rod. In addition, a groove of varying depth was machined into the side of each strut to accommodate the fins of the uranium fuel cans.

Every part of every strut had to be absolutely free from flaws which could give trouble during operation. The first problem, then, was to radiograph each strut in such a way that no significant imperfection could escape detection. The second problem was one of speed, because X-ray inspection had to keep pace with the flow-line production of the struts. This meant X-raying at least two struts a minute.

Mr. R. N. Beech, Head of Development at Powell Duffryn, tackled both problems by installing an X-ray booth in the production line. A special exposure tray was designed (by Inspection Equipment Ltd.) which enabled the radiographer to expose ten struts at a time, turn them through 90 degrees and move the struts relative to the film in the exposure tray to get a second exposure side-by-side with the first.

Kodak supplied 'Crystallex' X-ray Film cut to 24 × 24 inches* enabling the full length of ten rods to be exposed at one time. Thus Mr. Beech was able to obtain 20 images (two radiographs for each of ten rods) on one sheet of X-ray film.

The method is probably applicable to other inspection set-ups where it is an advantage to make two radiographs of a product side by side, and we have pleasure in passing the information on to readers of this journal.

Kodak LIMITED

at the service of inspection engineers

**This is a 'special order' item. Kodak will be pleased to discuss with you the design of special rigs or cassettes for unusual inspection jobs, and the provision of film cut specially to your needs. The film used in the case history quoted here was 'Crystallex', but there are five types of film available, covering every possible radiographic requirement.*

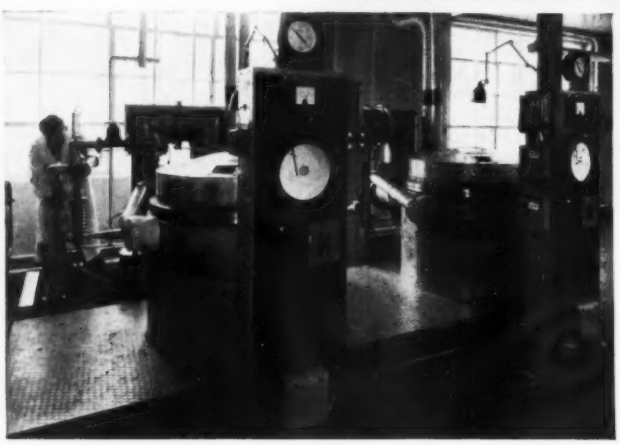
Kodak Limited, Industrial Sales Division, Kodak House, Kingsway, London, W.C.2

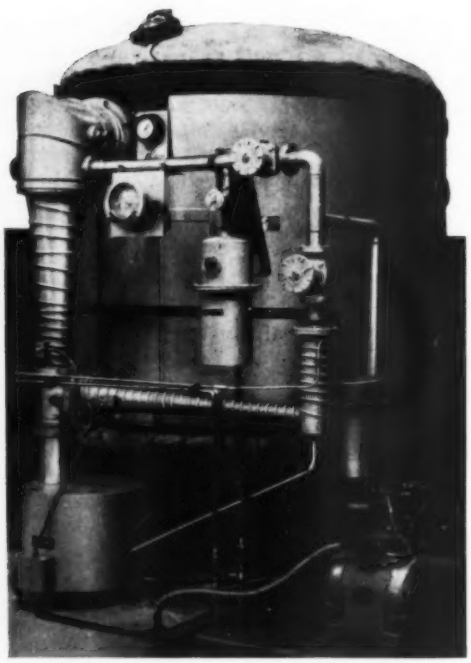
Tick **No 56** on reply card for further details

High Vacuum Impregnation and Degassing

EDWARDS

ENGINEERING DIVISION





Whilst atomic energy is a comparatively new industry EDWARDS have designed and built special high vacuum plant for its development since the very beginning.

The vacuum impregnation and degassing plant shown above was designed for the United Kingdom Atomic Energy Authority and is another example of the work carried out by our High Vacuum Engineering Division.

Above:
Complete "SPEEDIVAC" impregnation and oil degassing plant comprising, on the lower floor, twin impregnation chambers each pumped by 9B3 vapour booster pumps to ensure processing in the micron range. Vacuum measuring is provided by thermal (Pirani) type gauges mounted in console cabinets with recording equipment. The upper floor contains the primary and secondary oil degassing chambers also pumped by vapour booster pumps to ensure complete degassing of the oil before its transfer by gravity to the impregnation vessels below.

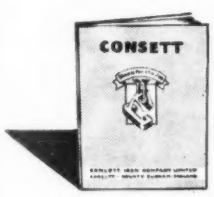
Left:
A specially constructed plant for processing experimental insulation assemblies and the investigation of vacuum drying of insulation at pressures of 0·1 torr and below.

EDWARDS HIGH VACUUM LTD., MANOR ROYAL, CRAWLEY, SUSSEX, ENGLAND. *Crawley 1500*

Terra-cotta Kylix — Ancient Greek workmanship around 520 B. C.

Something special...

The pride of the craftsman in his skill results in a perfection that is ageless. Here at Consett we are proud that time serves only to increase our reputation as producers of fine quality mild and special steels for particular applications. We have recently produced a most interesting and informative booklet — "Steels for the job" — which we think you should read. May we send you a copy?



STEEL FROM CONSETT

CONSETT IRON COMPANY LIMITED · CONSETT · CO. DURHAM
Telephone: Consett 341 (12 lines) Telegrams: Steel Phone Consett

Our Technical and Research Department will also welcome enquiries from any whose problem is . . . . STEEL

Tick **No 58** on reply card for further details

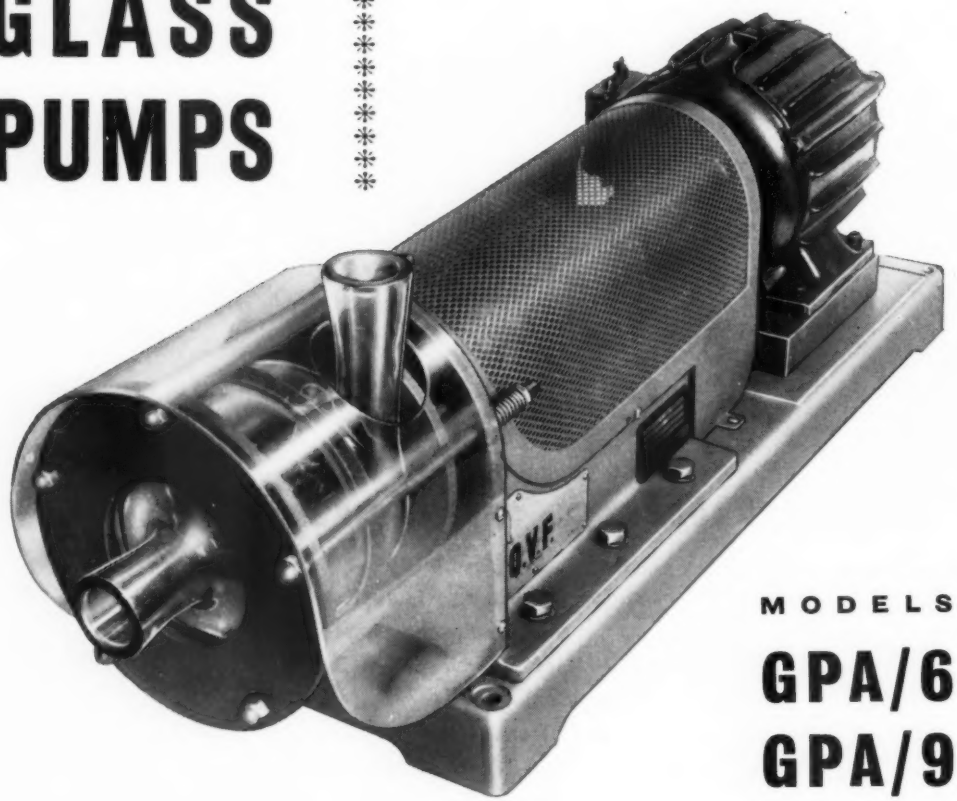
NEW FROM Q·V·F— GLASS PUMPS

These new Q.V.F. centrifugal type Glass Pumps are ideal for conveying liquids of water-like consistency.

Special features include—

- **Impeller of simple design based on a vortex type inlet with specially designed arms.**
- **Mechanical Seal is a glass-loaded Fluon Bellows rotating on a glass plate.**
- **Specially designed bearing chuck holds precision ground impeller shaft.**

Further details on application.



MODELS

GPA/6
GPA/9

Q·V·F·
LIMITED
The Chemical Engineers in Glass

DUKE ST · FENTON · STOKE-ON-TRENT
STAFFORDSHIRE

Telephone: LONGTON STAFFS 32104-8
Telegrams: Q.V.F., STOKE-ON-TRENT, TELEX

REWARD

A substantial and well-deserved REWARD has accrued to the above Company Director for his heroic, dogged, rugged—nay, sensible—decision to obtain from **ASSOCIATED LEAD** all his firm's supplies of **LEAD, TIN, ANTIMONY and their alloys, including 99.999% PURE LEAD, TIN & ANTIMONY, LEAD SHEET & PIPE, NUCLEAR SHIELDING, SOLDERS, ANTIFRICTION MATERIALS, ANTIMONIAL LEAD & CABLE ALLOYS.** He now moves in an aura of profit and prestige.

This announcement is issued for and on behalf of

ASSOCIATED LEAD MANUFACTURERS LIMITED

CLEMENTS HOUSE, 14 GRESHAM STREET, LONDON, E.C.2. CRESCENT HOUSE, NEWCASTLE. LEAD WORKS LANE, CHESTER

Export enquiries to: Associated Lead Manufacturers Export Co. Ltd., Clements House, 14 Gresham Street, London E.C.2

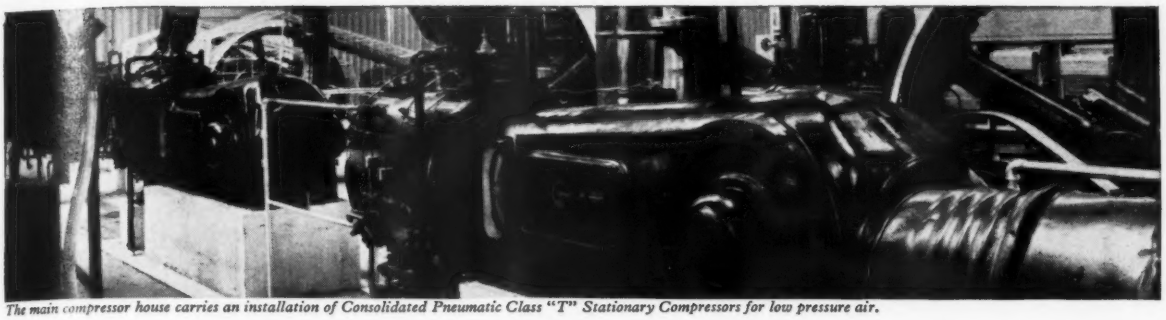
Many Consolidated Pneumatic "Power Vane" portable rotary air compressors are in service at Hinkley Point.

At Hinkley Point Atomic Power Station

CP equipment is working

Difficult conditions for drilling, but all in a day's work to the Consolidated Pneumatic G-800 Tracdril, shown drilling 4" holes to 40-ft in hard shale and limestone to clear a channel for the floating caisson.

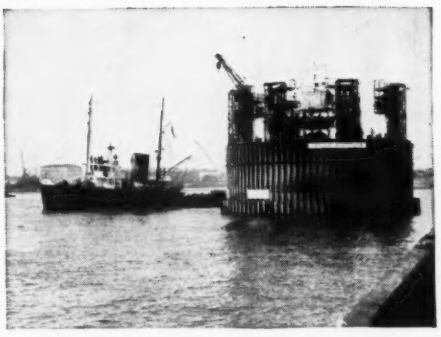
CP/195



The main compressor house carries an installation of Consolidated Pneumatic Class "T" Stationary Compressors for low pressure air.

hard for Taylor Woodrow...

Wherever big construction projects are going on, invariably CP air compressors and power tools will be found hard at work on the site. A good example of this is to be seen at Hinkley Point Atomic Power Station which is being built for the Central Electricity Generating Board by The English Electric, Babcock & Wilcox, and Taylor Woodrow Atomic Power Construction Company Limited. The civil engineering contractors, Taylor Woodrow Construction Limited are using a big proportion of CP equipment for every type of duty, not only to save time and man-power but also to maintain their high standards. These pictures will illustrate the complexity of operations being carried out at Hinkley Point. The excellent progress achieved by Taylor Woodrow reflects in some measure the efficiency of the CP equipment they have chosen for this work.



The floating caisson being towed out to its location at the seaward end of the tunnel. Three Consolidated Pneumatic "Power Vane" rotary compressors were installed in the caisson.

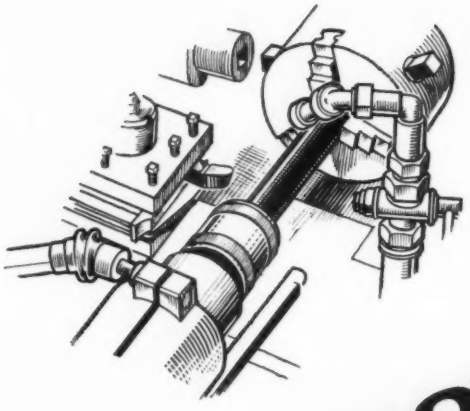
A CP pneumatic chain saw proves a great time saver for the many timber construction jobs occurring on a big contract.

Removal of water is a frequent problem on contracting work. The rugged CP-77 Sludge Pump can be relied upon for continuous duty in the roughest conditions.

Consolidated Pneumatic

CONSOLIDATED PNEUMATIC TOOL CO LTD · DAWES ROAD · LONDON · S.W.6

Tick **No 62** on reply card for further details



REMOTE CONTROL

The remote handling and machining of radio-active materials calls for design and construction of equipment by engineers who have a sound background in special-purpose machinery and machine tool production. More important, they must have a detailed knowledge and appreciation of the problems peculiar to the Nuclear Industry.

J. EVANS & SON (Portsmouth) LTD

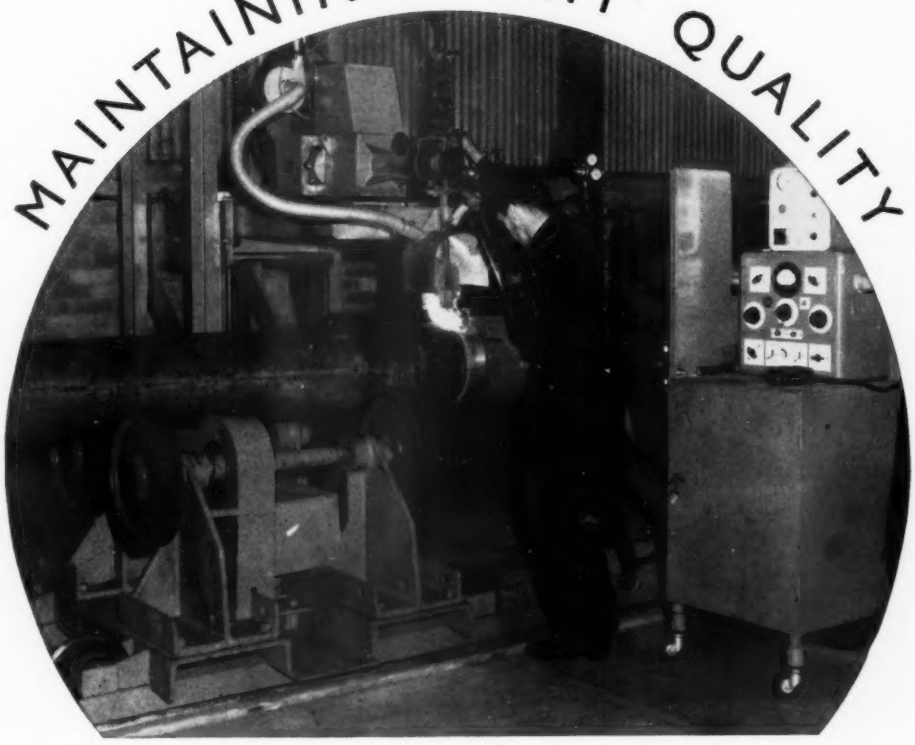
We have both the engineering skill and "know-how." With the close collaboration of the United Kingdom Atomic Energy Authority, we have already designed and installed equipment at the Dounreay, Windscale and Springfields plants.

The illustrations show the exterior and interior installation of a remotely controlled precision lathe for the machining of irradiated fuel elements at Dounreay.

We shall be pleased to visit you at any time and you are cordially invited to our works where selected films and a most interesting range of activities can be seen.

MARCYN WORKS,
GOLDSMITH AVENUE, PORTSMOUTH
Telephone: PORTSMOUTH 32233

MAINTAINING 'UNIT' QUALITY



UNIT tubular welded fabrications, for high or low pressures for industrial plants, are produced with specialized equipment. Quality of the highest standard is consequently maintained.

Illustrated is our latest Fusarc CO_2 automatic installation, welding a circumferential butt joint on a reactor standpipe for Bradwell power station. The welds are one hundred per cent radiographed to a high standard of acceptance and are subject to the survey of Lloyds Register of Shipping.

'Unit' specialities include water-wall headers, steam and oil receivers, de-superheater bodies and tubular products of all descriptions for every kind of power station and for industrial steam raising plants.

THE UNIT SUPERHEATER UNIT AND PIPE COMPANY LTD

UNIT WORKS, SWANSEA · *Telephone:* SWANSEA 54091 *(6 lines)* · *Telegrams:* 'SUPERUNITS', SWANSEA · *Telex:* 4835

Tick **No 64** on reply card for further details

The practical vision of Steve Blank

The uncluttered layout and clean typography of the pages of this magazine are no accident. They are an expression of the art of Steve Blank and other specialists like him.

Mind you, Steve is not too happy about our use of the word 'art'. He is essentially a practical engineer who believes that a technically authoritative journal should above all things be absolutely clear.

That is why, for example, all our articles begin and end on full pages* without breaks; why graphs and diagrams are so meticulously drawn and captioned; why *Nuclear Power* looks so different from any other technical magazine in the world.

*This easy-to-file layout system is specially useful to engineers who maintain private reference files. A pre-paid subscription card will be found facing page 102.

Rocol

anti-scuffing products are

BROAD-MINDED

lubricants

A Rocol PRODUCT

Rocol Anti-scuffing Products provide the best means of applying Molybdenum Disulphide — the most advanced lubricant known to engineering science — to all rubbing surfaces.

ANTI-SCUFFING PASTE. In paste form for general purpose use.

ANTI-SCUFFING OIL. For reinforcement of all lubricating oils.

ANTI-SCUFFING SPRAY. In aerosol form — containing bonding resin.

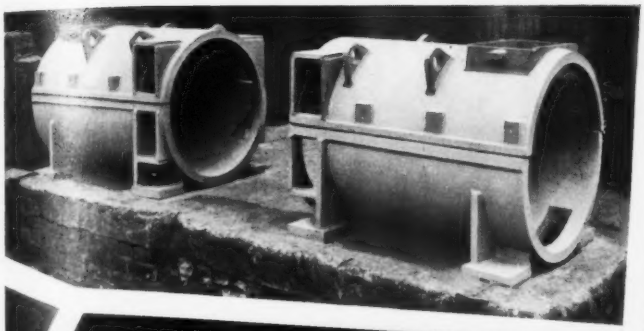
Our Technical Information Service will provide any further information you may require about these and other Rocol Molybdenised Lubricants.

Rocol

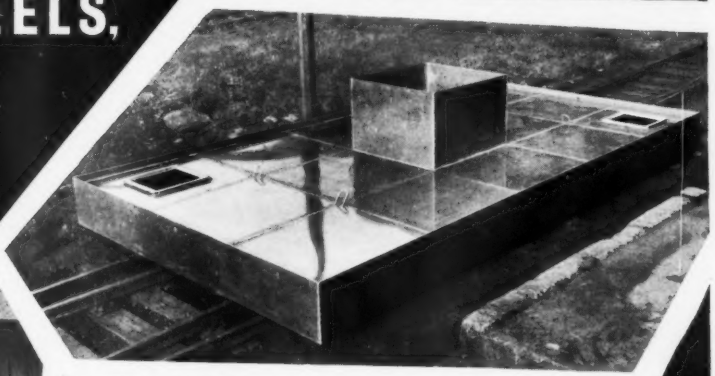
MOLYBDENISED LUBRICANTS

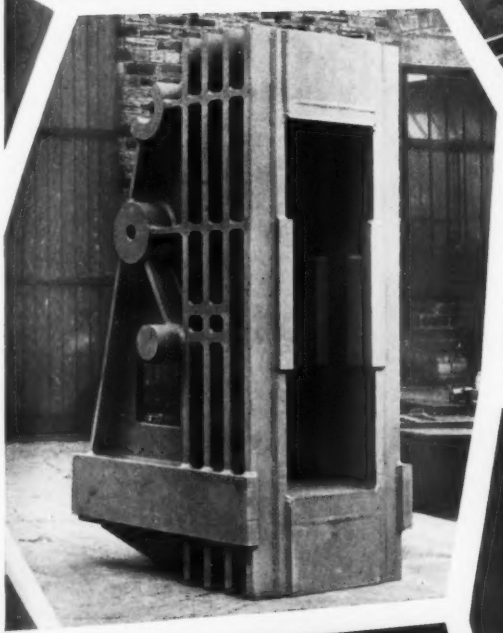
ROCOL LIMITED
GENERAL BUILDINGS · ALDWYCH · LONDON, W.C.2. Tel: HOLborn 1985.
ROCOL HOUSE • SWILLINGTON · LEEDS · Tel: Garforth 2261.

1078xa



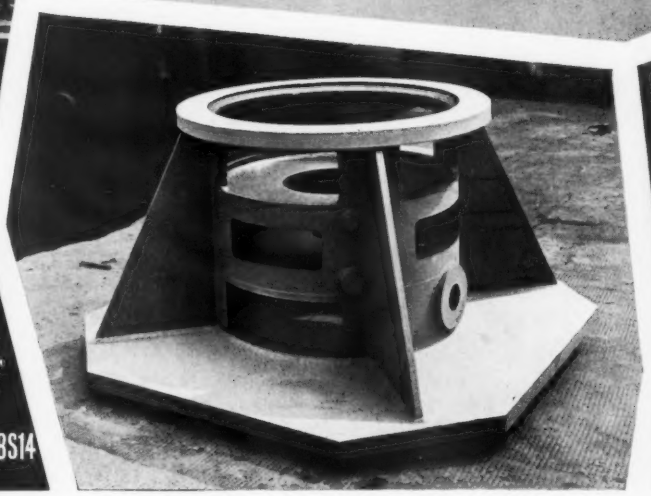
For General Fabrication in MILD STEELS, STAINLESS STEELS, and ALUMINIUM ALLOYS





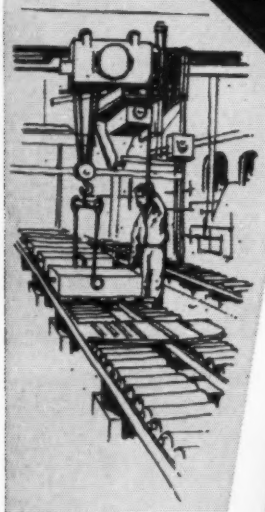
ROBERTSON & FERGUSON LTD.

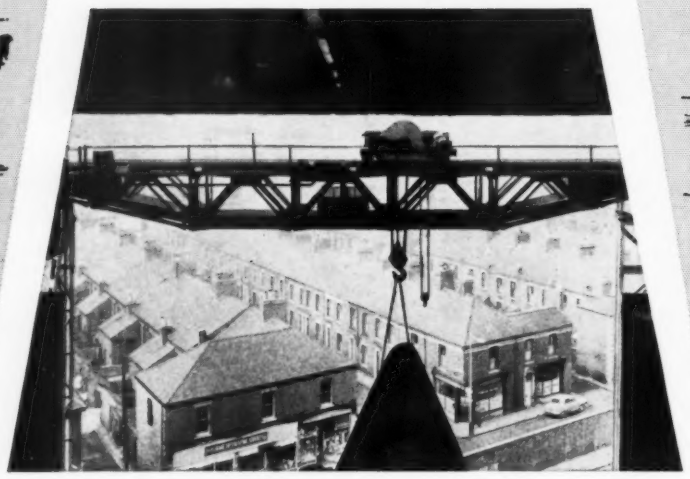
29 MURIESTON CRESCENT, EDINBURGH, 11. Tel: DON 5222

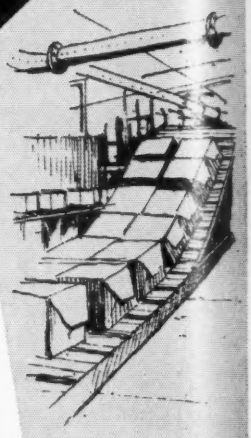


WE ALSO SPECIALISE IN DISHED AND FLANGED ENDS MAX. DIA. 24" MAX. THICKNESS ½" Made to suit Customer's inspection requirements from BS14

PATERSON HUGHES
ENGINEERING COMPANY LIMITED





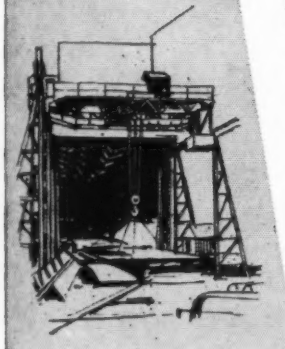


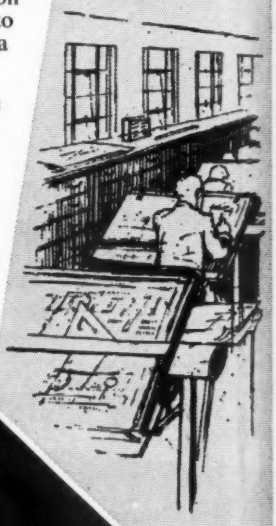
A Paterson Hughes 30-ton electric overhead travelling crane at Blyth Dry Dock and Shipbuilding Co. Ltd.—by whose courtesy this photograph is reproduced.

Paterson Hughes cranes are built in their modern crane shop in Scotland to designs based on their 35 years of experience in this field.

If the Paterson Hughes range—from hand jibs to 100-ton overhead cranes—does not include a standard model suited to your exact needs, then a special will be designed at a competitive price.

Paterson Hughes engineers will also design complete crane systems, extending from your goods inwards bay to the finished products warehouse, bearing in mind the special requirements of each industry.





THE PATERSON HUGHES

CRANE DIVISION

Specialists in modern crane practice

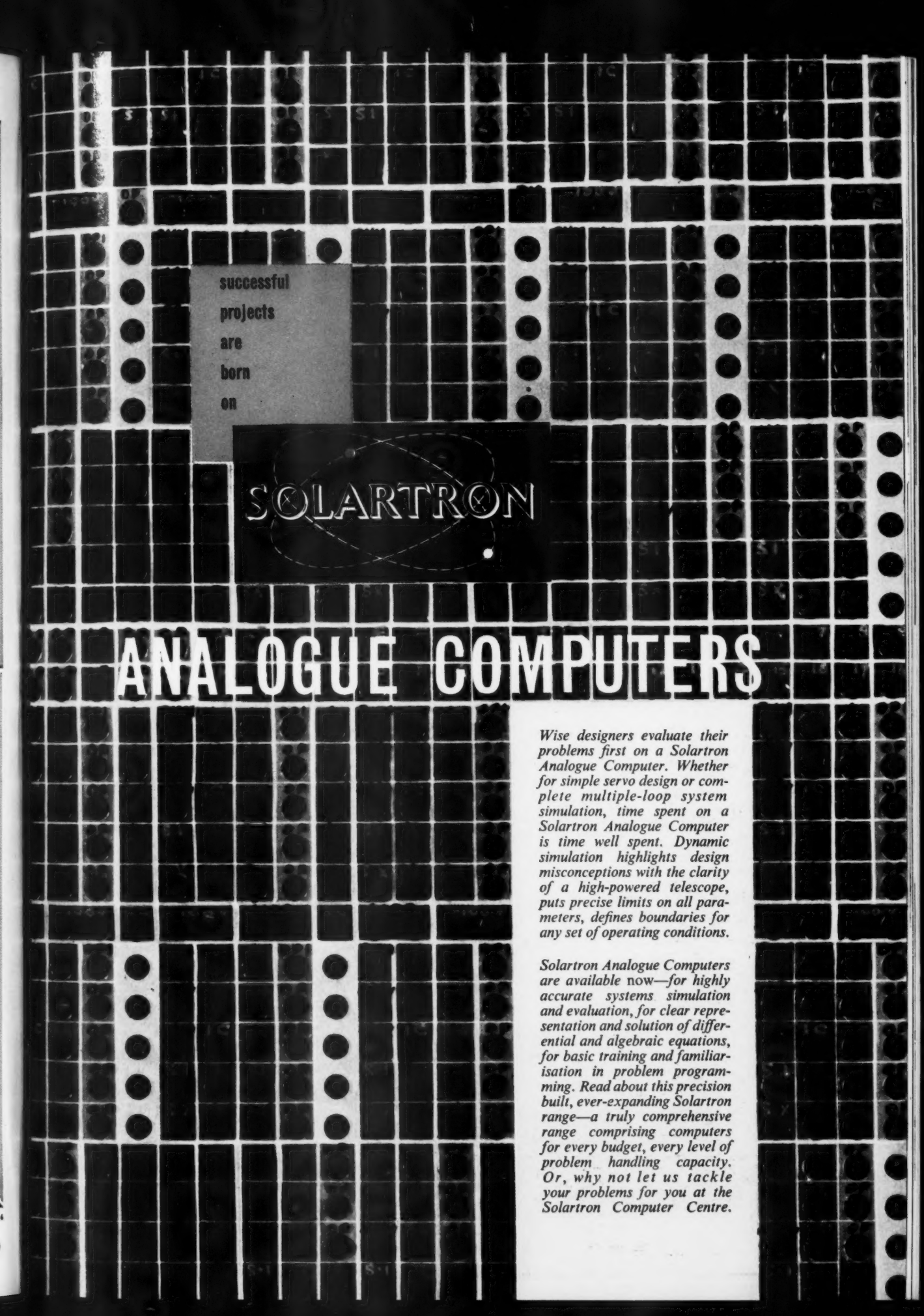
BIRMINGHAM
3 Highfield Road
Edgbaston Birmingham 15
Phone: Edgbaston 2957-8

GLASGOW
Wyndford Works
Maryhill Glasgow
Phone: Maryhill 2172-4

SOUTH AFRICA—Paterson Hughes Engineering SA (PTY) Ltd PO Box 811 Johannesburg

LONDON—Bedford House Bedford Street London WC2 Phone: Temple Bar 7274-6

P.2114



Wise designers evaluate their problems first on a Solartron Analogue Computer. Whether for simple servo design or complete multiple-loop system simulation, time spent on a Solartron Analogue Computer is time well spent. Dynamic simulation highlights design misconceptions with the clarity of a high-powered telescope, puts precise limits on all parameters, defines boundaries for any set of operating conditions.

Solartron Analogue Computers are available now—for highly accurate systems simulation and evaluation, for clear representation and solution of differential and algebraic equations, for basic training and familiarisation in problem programming. Read about this precision built, ever-expanding Solartron range—a truly comprehensive range comprising computers for every budget, every level of problem handling capacity. Or, why not let us tackle your problems for you at the Solartron Computer Centre.

SOLARTRON

training

research

full scale

any size

ad infinitum

AMONG THE USERS OF SOLARTRON COMPUTERS ARE

A.E.I. (Heavy Plant Divisio

British Nylon Spinners

English Electric

G.E.C.

Hawker Siddeley Group

I.C.I.

C. A. Parsons

Royal Aircraft Establishment

U.K.A.E.A.

United Steel

1 analogue tutor

Capable of demonstrating any form of second-order differential equation. Applications include representation of servos, simple electrical networks, motion of particles and like systems.

• complete

iniature

omputer

for

Student

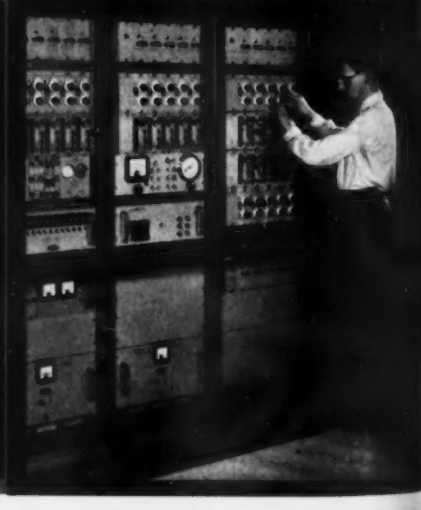
use

It is safer and cheaper to simulate mistakes than make the
Without having to build it, here is your projected syste
brought to your very desk-side or laboratory!

The Solartron SPACE '30' analogue computer (right) is unique in flexibility of application. With an operational capacity greater than many computers using 40 or more amplifiers, SPACE '30' has an additional problem-beating complement of non-linear units for direct analogue simulation of almost any dynamic system. Even when many complex system elements must be included as analytic or empirical non-linear operators, SPACE '30' will faithfully simulate according to the known information to produce a highly accurate prediction of dynamic performance.

4

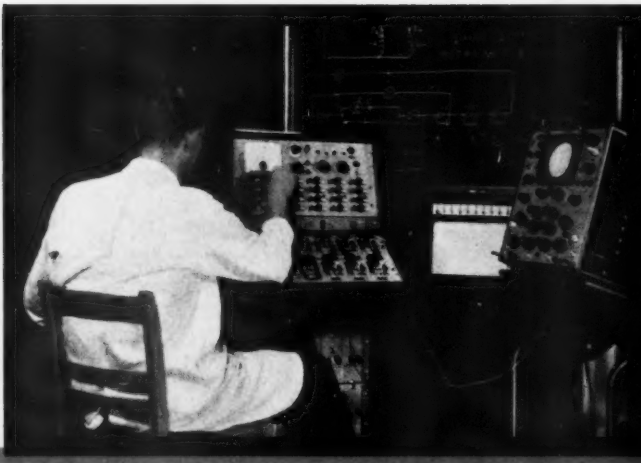
All Solartron analogue computers are built using a highly flexible modular construction technique. Thus at any time, your Solartron machine need only be as complex as budget and work demand. Special machines, like the Auto-Control Simulator illustrated here, or the SPACE '30' series, can be expanded or multiplied at a moment's notice.



ANALOGUE COMPUTERS

The Analogue Computer is the foremost aid to training in feedback techniques and theoretical servo analysis, also for clearly representing and solving complex differential equations.
Because of its common basic approach to all dynamic problems, analogue computing practice is vital to broadening engineering appreciation. Parallels between widely different systems are drawn with sudden lucidity — between hydraulic controls and national economics for example, or between a nuclear reactor and a controlled biological culture. Every problem solved on an analogue computer brings a wealth of dynamic knowledge, relevant to wide areas of subsequent work.

MINISPACE * Provides high accuracy at low cost * Ideal for servo simulation and basic reactor studies for students. * Eminently suitable for sub-programming larger machines.



2 minispace

- ★ Solves linear or non-linear problems: up to 5th-order differential equations.
- ★ Easily expanded to greater problem capacity.

For handling even bigger problems, your SPACE '30' installation can be multiplied to give 60 or 90-amplifier capacity—or, in the preferred case, you can choose a SPACE '60' or SPACE '90' machine, each fully integrated for centralised programming and control.

3 space '30'

- ★ 30 amplifiers in new, optimised design configuration.
- ★ Full complement of non-linear computing elements.
- ★ The first choice for complex dynamic simulation of any kind.
- ★ Easy to use — easily expanded.

FOR INDEPENDENT USE

These three Solartron Analogue Computing Units are typical of many which exist in their own right as precision instruments and which are immediately available for use independently, or in existing analogue computing installations.

Full technical literature is available on request.

- 12-Segment, high accuracy function generator, ± 100 V output, 0.5% long-term stability.
- Rapid, accurate break-point setting in Cartesian co-ordinates, by digital volt-meter.

5 diode function generator TR 829

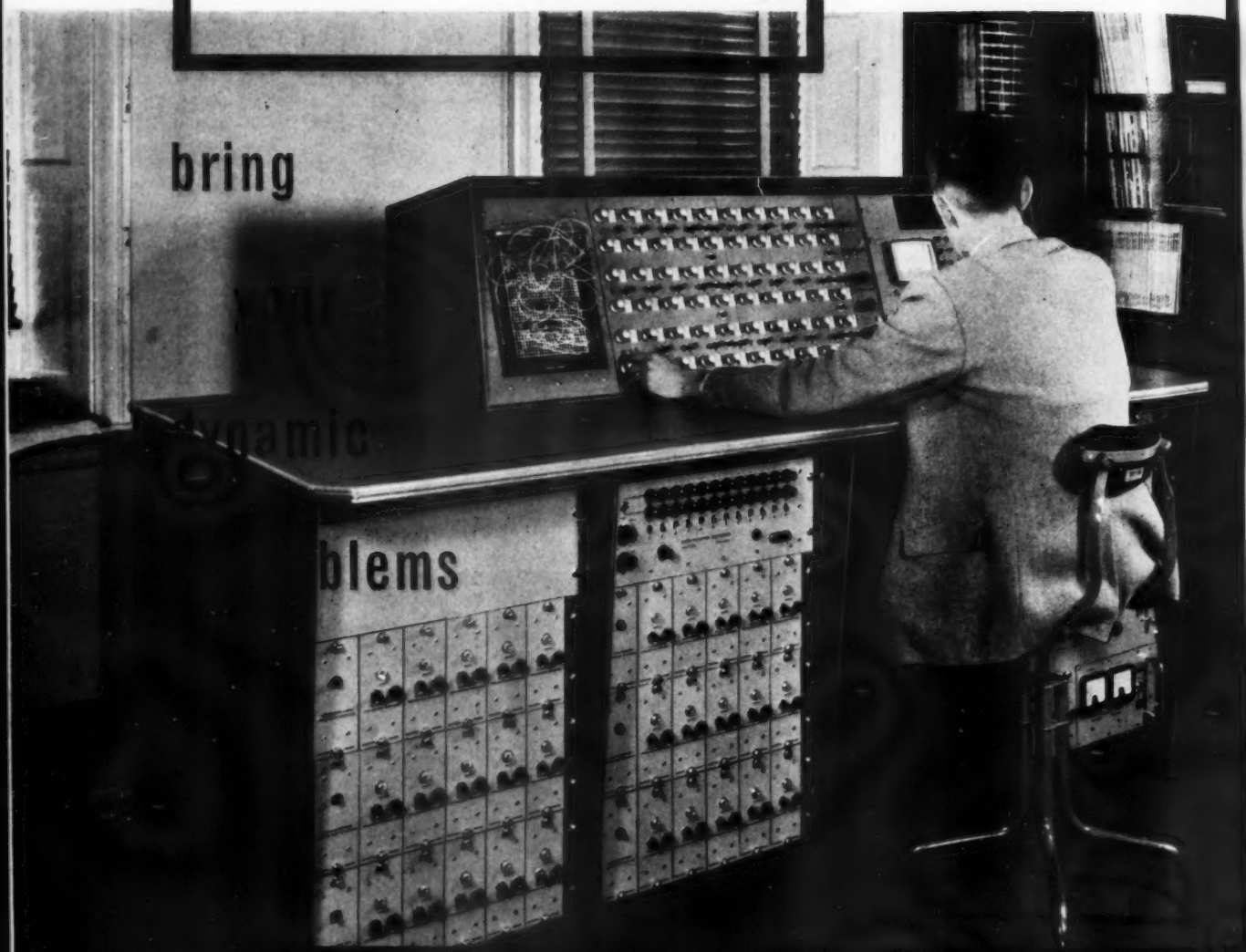
- Fastest response available: accurate f.s.d. up to 10 c/s.
- Six-section pot, driven directly from servo.
- Self-contained with transistor feedback amplifier and power supply.
- Multiplies up to five variables by one other or generates up to sixth power.

6 servo multiplier TJ 725

- 0.005% limit on deviation between positive and negative 100V supplies. NPL certificate on request.
- Better than 0.1% long term accuracy and 4,000 to 1 stability ratio.
- Incorporates Weston cell as reference source.

7 precision reference power supply AS 756/2

THE SOLARTRON Computer Centre at the Dorking Research and Development Laboratories of the Solartron Group offers comprehensive facilities for dynamic problem evaluation, programming and detailed solution on SPACE '30' Analogue Computers. Skilled personnel will, if you require, translate your problems into computer language and carry out all the operational procedures.



SOLARTRON COMPUTER CENTRE

address your enquiries to:

THE SOLARTRON ELECTRONIC GROUP LIMITED (Computer Division)
Victoria Road, Farnborough, Hampshire. Telephone: Farnborough (Hants) 3000

Here's another one!

Contactor control gear for all schemes. Unbreakable jointless & and rustless resistances. MICROsen speed control for AC slip ring motors. Drum & contactor type controllers.

EMB technical representatives

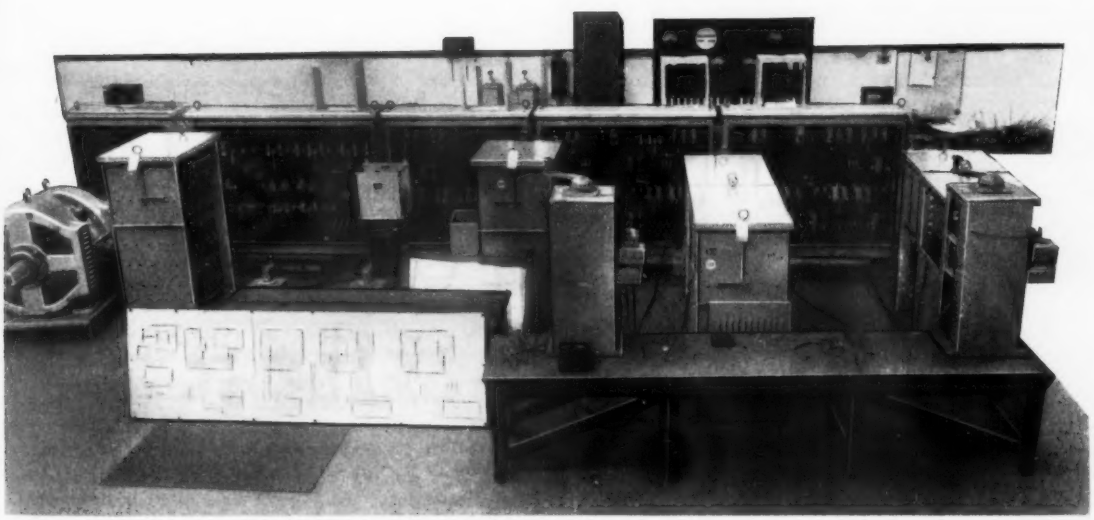
London	Midlands	Lancs & Yorks	Scotland
R. S. Montgomerie	C. Cleveley	S. J. Pitt	L. Hopwood
P. N. Jay			
Northwood	West Bromwich	Sheffield	Glasgow
2159	1171	55278	Giffnock 0188

Control gear for the Babcock & Wilcox charge floor crane at Hinkley Point took $^{3}/_{4}$ mile of cable to connect up for testing and quite a time too.

But on this kind of job everything must be right.

That's why so many Atomic Energy Establishments have EMB control gear.

Specify EMB for standard control gear equipment as well as complicated control schemes.



E.M.B. Co Ltd

WEST BROMWICH
Phone:- 1171
ENGLAND

CONTRACTORS TO THE ADMIRALTY, CROWN AGENTS TO THE COLONIES, SUPPLY DEPARTMENTS, DOMINION AND OVERSEAS GOVERNMENTS

NOW !

HYDRAULIC CIRCUITS

HYDRAULIC A-Z

can be bought in a package !

THE ARMSTRONG HYDRAULIC ACTUATOR

enables you to install first-class hydraulic circuits in the easiest and most economical way in the world.

You can select a combination of the various types of Armstrong Actuator units to suit your individual requirements. Accurate assembly requires only elementary engineering knowledge; simple instructions are provided and stock embodiment items supplied.

An Armstrong Actuator does away with the need for heavy or complicated linkages and gives none of the troubles that tend to crop up with links, levers or cams. Once installed and charged, it will function for as long as the machine or structure in which it is embodied—smoothly and efficiently. This bold new conception of hydraulic control has behind it the vast experience gained by the Armstrong Patents Company Limited of Beverley. They alone, because of their unique position in the field of hydraulic engineering, are able to offer Actuators of this quality at the price.

Armstrong "Off-the-Shelf" Actuators — power or manually operated — put so many possibilities "within your reach" that early investigation is advised. Ask for leaflet :—APL 51/21.

ARMSTRONG PATENTS CO. LTD.
EASTGATE, BEVERLEY, YORKS. Tel. Beverley 82212

The silhouettes of the atomic power stations, strange and new a year or two ago, are today familiar to technical men.

Keeping pace with new developments for over 75 years, 'Tornado' fan engineering equipment now finds itself quite at home in these strange landscapes, assisting in the exacting work of the UKAEA establishments. Among the equipment we have supplied for Dounreay is fan equipment for the vessel ventilation system, the Highly Active Liquor Store and the Billet Production Plant.

In addition, equipment has been installed at Aldermaston, Capenhurst, Foulness, Harwell, Risley, Springfields and Windscale and other Keith Blackman fans and blowers are being used experimentally elsewhere. If the problem involves the handling of air or other gases, contact

Keith Blackman Ltd

MILL MEAD ROAD LONDON N17

BIRMINGHAM · BRISTOL · GLASGOW · LEEDS · LEICESTER · MANCHESTER · NEWCASTLE

Tornado

'Tornado' equipment includes: CO_2 Coolant Blowers and Heat Exchanger Cooling Fans. Fans for Ventilation, Dust Removal and High Temperature Extraction. Blowers for Gas Boosting, Dry Scrubbers and Vessel Ventilation. Also Air Sampling Compressors, Air Flow Control Units, Back Pressure Valves, Steel Fabrications and the Keith Blackman-Broman Ekstrom Shot Cleaning of Heat Exchangers.

TA2315/988

Tick **No 76** on reply card for further details

Stainless Steel Forgings

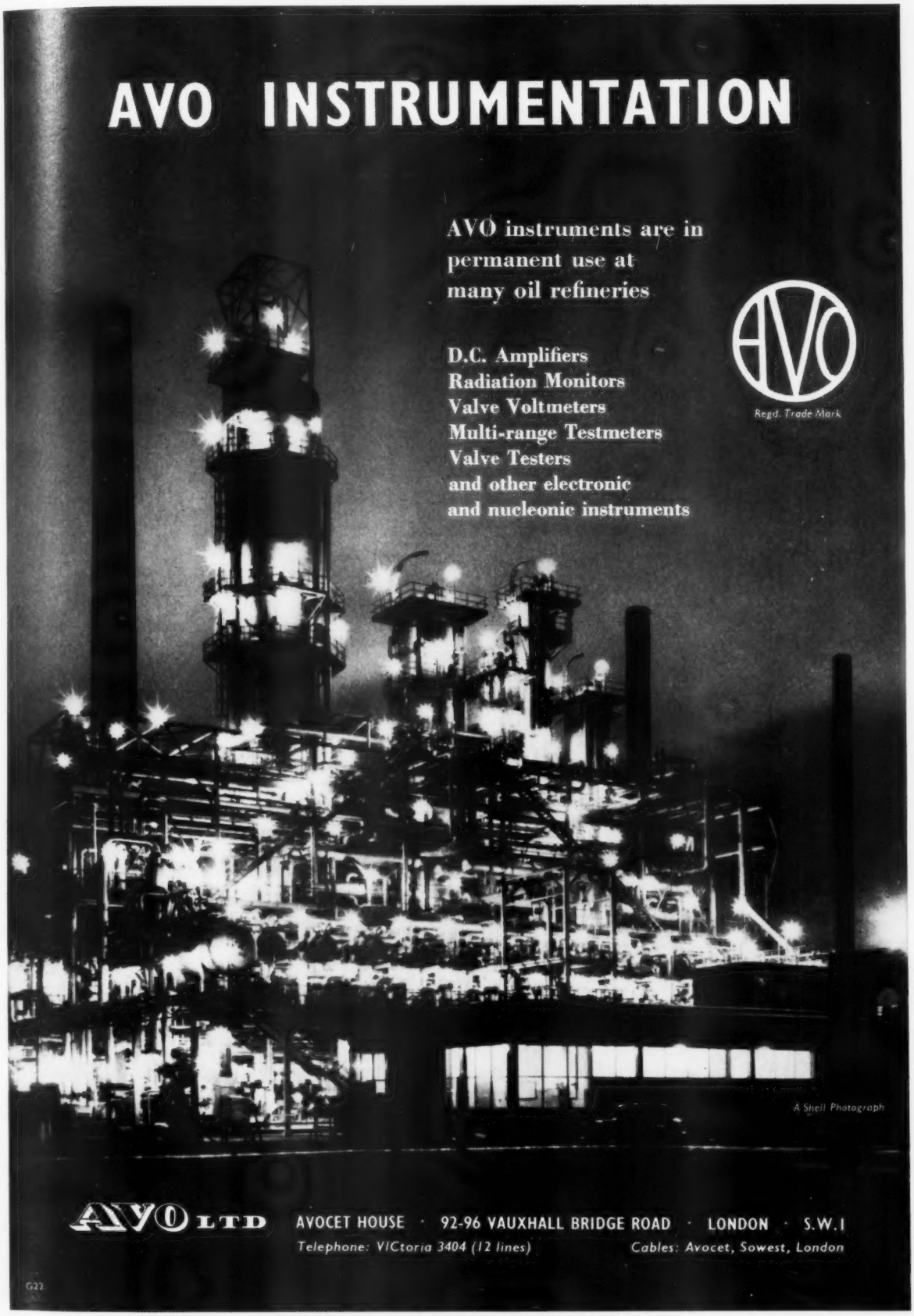
serving Atomic Energy, Aircraft and Oil industries

Manufactured to any British or U.S.A. Standard Specification
Supplied as Forgings only or Fully Machined in Modern Machine Shops on approved lists of A.I.D., A.R.B. and LLOYDS.

William Oxley & Co. Ltd.

PARKGATE STEEL WORKS · ROTHERHAM
telephone Rotherham : 5238

AVO INSTRUMENTATION



AVO instruments are in permanent use at many oil refineries

D.C. Amplifiers
Radiation Monitors
Valve Voltmeters
Multi-range Testmeters
Valve Testers
and other electronic and nucleonic instruments

AVO

Regd. Trade Mark

A Shell Photograph

AVO LTD AVOCET HOUSE · 92-96 VAUXHALL BRIDGE ROAD · LONDON · S.W.1

Telephone: VICtoria 3404 (12 lines) *Cables: Avocet, Sowest, London*

G22

A MEMBER OF THE METAL INDUSTRIES GROUP OF COMPANIES

A Vital contribution to Atomic Power . . .

"WANDLESIDE"

ARMOURED CABLE

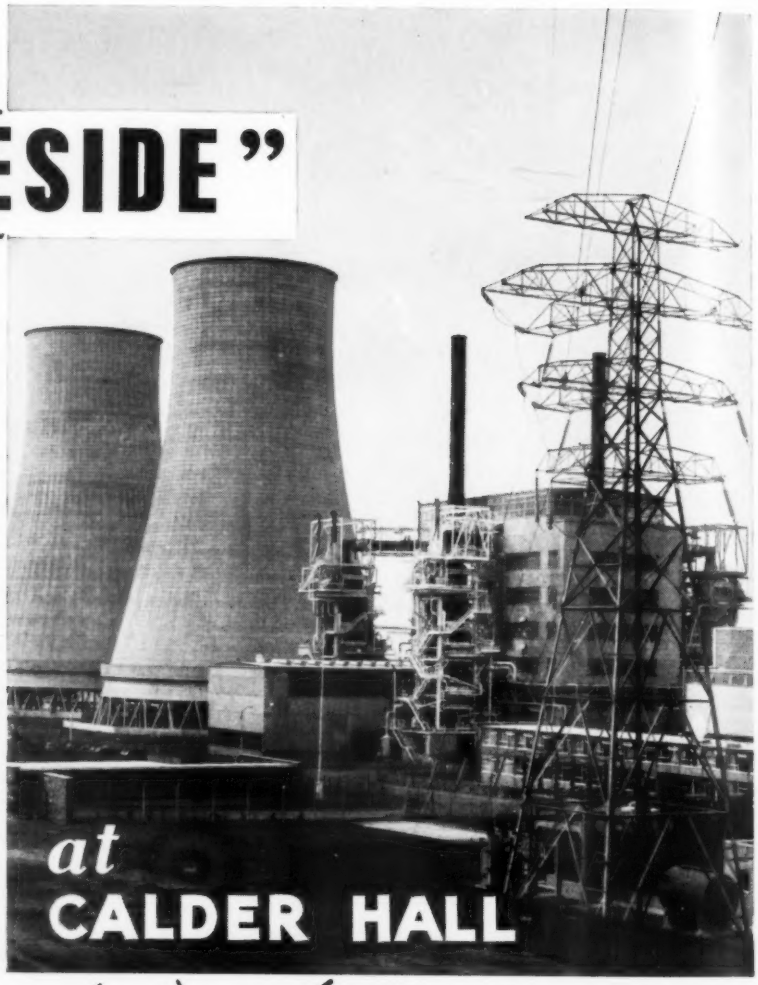


Photo by courtesy U.K. Atomic Energy Authority

With the advancement of Atomic Power, cables must play an important part in the efficiency and reliability in the production of Nuclear Energy. Only the best is good enough and Wandleside Cables are eminently suitable.

WANDLESIDE CABLES *for Nuclear Energy*

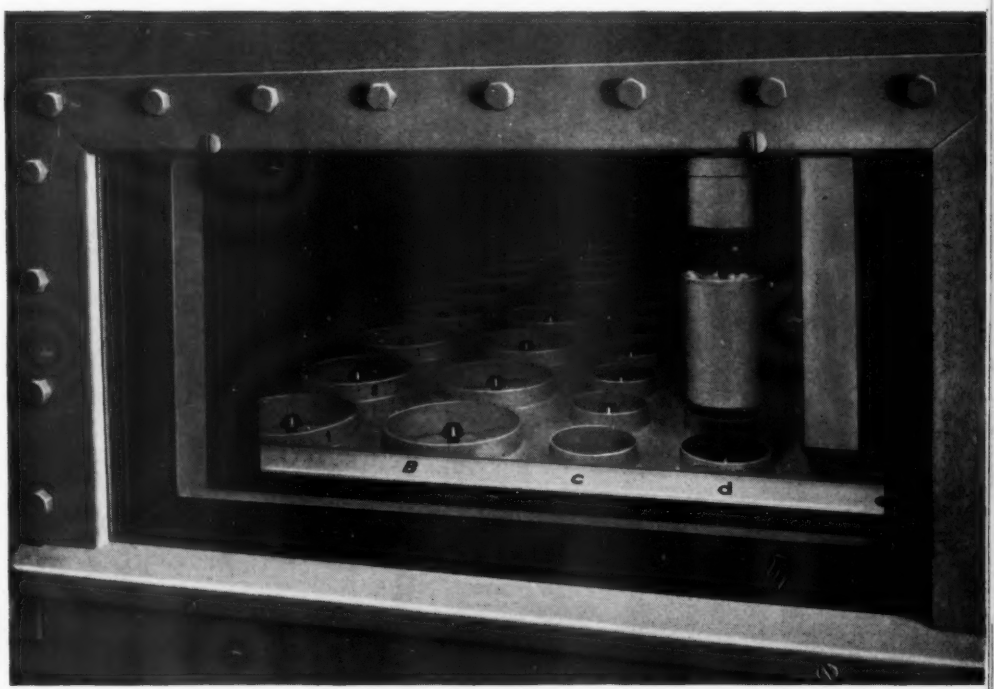
Visit us on Stand T11 at A.S.E.E. Exhibition. April 5—9, Earls Court

WANDLESIDE CABLE WORKS LTD. 106 GARRATT LANE WANDSWORTH LONDON, S.W.18
One of FALKS Group
Telephone: VANdyke 7544 (5 lines) *Telegrams: Wandleside, London*

PROTECTIVE GLASSES

against Radio-active Radiation

There are 10 types available with varying lead content and in densities from 2.53 to 6.20. Among those there are also several stabilized types which will not become brown even under exposure to high radiation doses. The great number of glass types permits good adaptation of the thickness of the windows to that of the protective walls. Depending on glass type it is possible to produce blocks in sizes up to 1,3 m at thicknesses from 15 to 30 cm.



For further use in nuclear research we supply

Bubble Chamber Windows
made of best optical glass in untempered and tempered quality. Even large windows can be tempered.

Cylindrical Blocks of Lead Glass for Cerenkov-Counters
of high refractive optical glasses, especially free from colour.

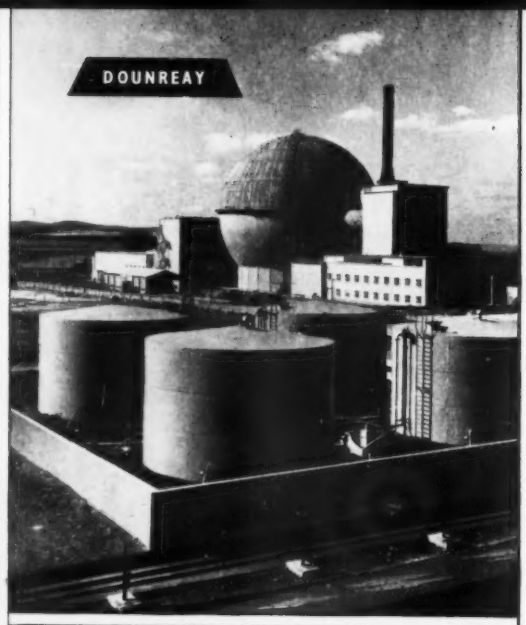
SCHOTT & GEN MAINZ

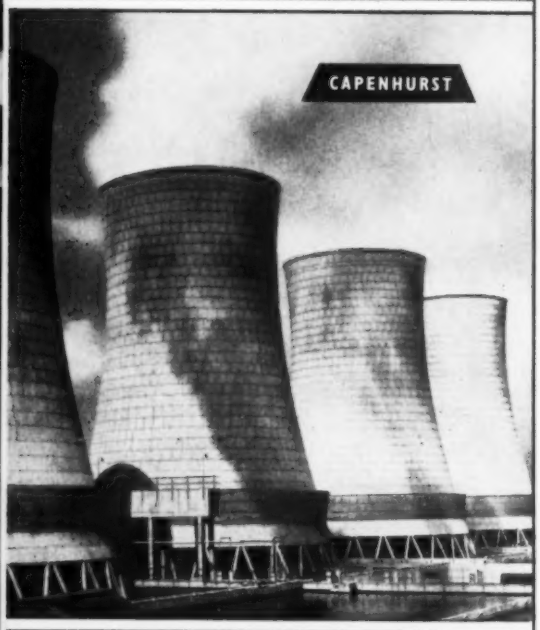
JENA[ER] GLAS

JENA[ER] GLASWERK SCHOTT & GEN., MAINZ

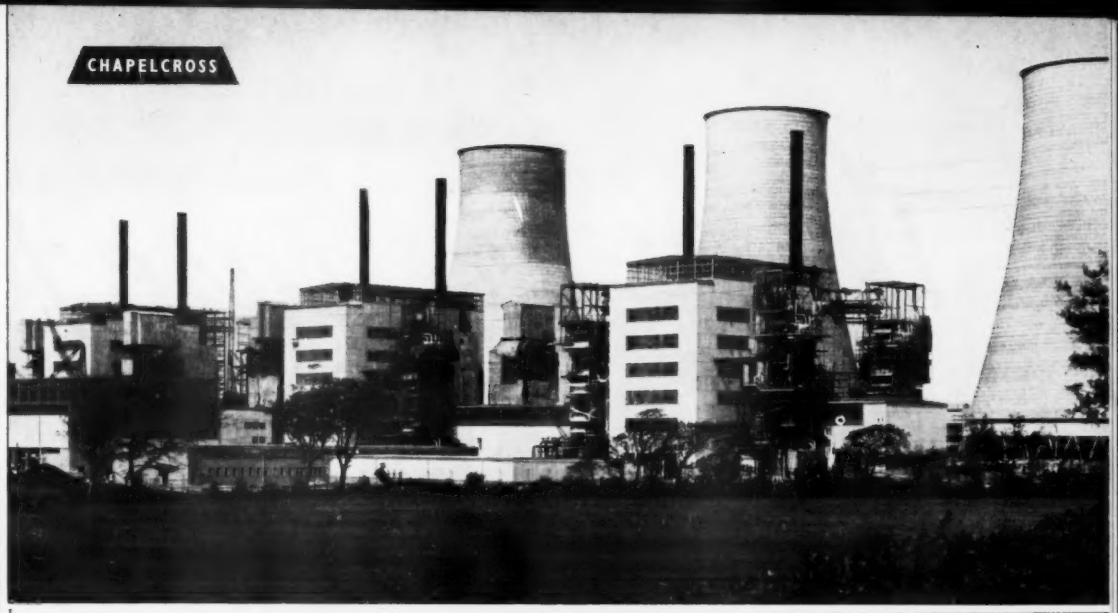
Western Germany

Tick **No 80** on reply card for further details


DOUNREAY


CAPENHURST

SPRINGFIELDS



MITCHELL COMPANIES

are preparing specialist

pipework and process

plant for the

U.K. Atomic Energy Authority

at Dounreay, Chapelcross,

Capenhurst & Springfields

MITCHELL

MITCHELL ENGINEERING LIMITED

ONE BEDFORD SQUARE LONDON

There's no excuse for
CORROSION

Many thousands of tons of steel are lost through corrosion every year and much of this can be saved. *There is a remedy.*
"Superlative" Metal Primer provides a positive protection against corrosion for all ferrous metals. It is quicker and easier to apply than conventional Lead Coatings and is infinitely cheaper. But, as *efficiency* is the factor that matters, and "Superlative" is so economical and so effective, it pays to specify

"*Superlative*"
METAL PRIMER

Kills **CORROSION AT THE SOURCE**

Our Techniservice will gladly answer all enquiries.

BRITISH PAINTS LIMITED
Portland Road, Newcastle upon Tyne, 2.
Northumberland House, 303/306 High Holborn, London, W.C.1. 31 Wapping, Liverpool, 1.

BY APPOINTMENT TO HER MAJESTY QUEEN ELIZABETH II MANUFACTURERS OF PAINT BRITISH PAINTS LIMITED

BELFAST · BIRMINGHAM · BRISTOL · CARDIFF · GLASGOW · LEEDS · MANCHESTER · NORWICH · PLYMOUTH
SHEFFIELD · SOUTHAMPTON · SWANSEA AND ALL PRINCIPAL TOWNS

Forged Steel Reinforcement Gas Duct Rings

As machined prior to installation 98″ o/d, 68″ i/d, overall width 24″ (by courtesy of Whessoe Ltd.)

As forged and heat treated 101″ o/d, 65″ i/d, overall width 27″ (by courtesy of Whessoe Ltd.)

As machined prior to installation for 3′ 3″ bore inlet duct and duct erection opening for heat exchangers (by courtesy of International Combustion Group)

For Spherical and Cylindrical Vessels as supplied for the above NUCLEAR POWER PLANTS

Material B.S.1503/151—1950, grade B, having excellent welding properties, with Charpy V notch impact results of 25 ft. lbs. average at − 10°C.

The Darlington Forge Ltd DARLINGTON

Tick **No 84** on reply card for further details

AIRMEC

INSTRUMENTATION

keeps in step with nucleonic needs

MONITORS

RADIATION MONITOR *Type 1021 B*

★ **SAFEGUARDS against contamination.**

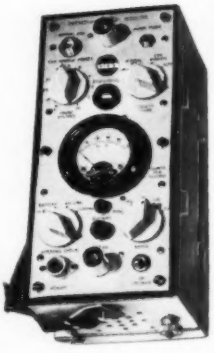
★ **TRACES radio-active material in chemical analytic processes.**

★ **MEASURES contamination of any resulting effluent.**

Designed in conjunction with A.E.R.E. Harwell, this instrument is probably the most widely used general purpose monitor in the world. It has been PROVED by years of user experience to be the most accurate and reliable equipment of its type.

The Radiation Monitor consists of a mains operated Indicator Unit together with a Beta Gamma or Alpha Probe Unit. Indication is provided visually by means of a meter which is calibrated in counts per second, and audibly by means of a loudspeaker. A socket on the front panel is also provided to enable the output to be fed to a scaling unit.

Write for descriptive leaflet No. 26D giving full details.



RADIATION MONITOR *Type 255*

★ **Transistorised, battery operated, portable.**

★ **Laboratory accuracy under field conditions.**

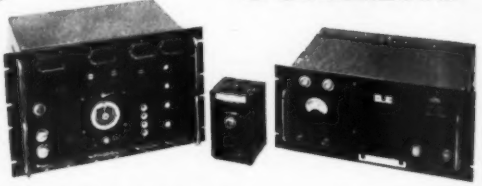
★ **Wide range of probes and accessories available.**

Airmec are proud to be the first to announce a fully transistorised monitor which combines laboratory accuracy with complete portability. The uses include:

1. Checking the presence and amount of radio-active contamination in laboratories and workshops.
2. Checking atmosphere 'fall-out' and contamination of food, animals, crops, milk and water supplies, etc.
3. Following the progress of radio-active tracer elements in medical, geological, agricultural and industrial processes.
4. Tracing the whereabouts of radio-active areas and making accurate assays of samples in geological surveys.
5. Tracing lost samples of radio-active materials both in buildings and out.

Write for descriptive leaflet No. 177

SCALERS



GENERAL PURPOSE COUNTER *Type 1339 A*

★ **Designed and developed in conjunction with U.K.A.E.R.E.**

★ **Provides comprehensive scaling facilities for all types of Geiger Scintillation Counters.**

★ **Incorporates stabilised E.H.T. supplies.**

★ **Fitted with automatic timing control.**

This equipment is built on a unit basis and provides very comprehensive scaling facilities for all types of accurate assay work. It consists of two main units — a Power Unit and a Scaling Unit — together with a number of optional sub-units. These include a Quenching Unit, a High Speed Scaling Unit, an Amplifier/Discriminator Unit, a Paralysis Unit and a Timing Unit.

Full details are given in descriptive leaflet No. 185

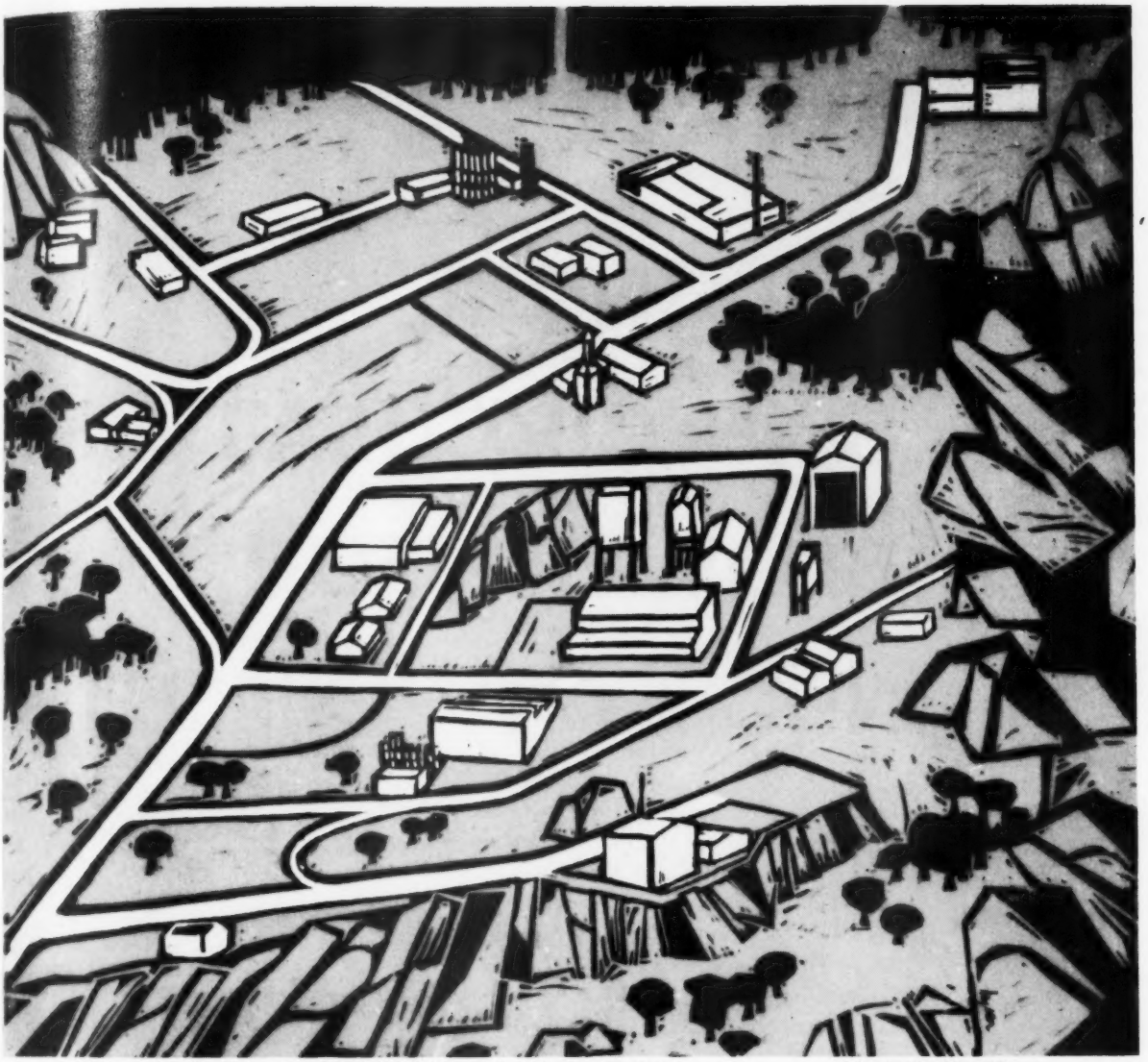
See this instrument at the
I.E.A. Exhibition, Olympia, May 23-28
STAND D162

Airmec

INSTRUMENTS FOR THE NUCLEONIC INDUSTRY

AIRMEC LIMITED · HIGH WYCOMBE
BUCKS

Telephone: High Wycombe 2501/7



AI's extensive field laboratory is located in California's Santa Susana Mountains. *Woodcut by Edward Kysar.*

How can A.I. facilities help you plan a Nuclear Program?

In the picturesque Santa Susana mountains near Los Angeles, Atomics International has built an extensive field laboratory for research, engineering and testing in the nuclear sciences. Here, and at a headquarters complex in the valley below, men who pioneered the creative uses of atomic energy are applying their experience to develop advanced nuclear reactors and associated equipment.

Fourteen years of experience in developing various types of reactors for the Atomic Energy Commission and other organizations have given the men of Atomics International a collective background unparalleled in the industry. The facilities at their disposal are among the most sophisticated and extensive in the world.

Results of AI's work have been demonstrated in projects for the AEC which include the Organic Moderated Reactor Experiment at the National Reactor Testing Station in Idaho and the Sodium Reactor Experiment at the company's field laboratory. Additionally, AI built and is operating SNAP II, a 220 pound prototype reactor to produce three kilowatts of electricity for space vehicles.

Atomics International is also building large power reactors for electric utilities in Ohio and Nebraska under AEC programs. Studies are underway for other power reactors in the United States and Europe. Research reactors have been built by AI for Denmark, Germany, Italy, Japan, Puerto Rico and several sites in the United States.

For details contact: ATOMICS INTERNATIONAL, Canoga Park, California, U.S.A. Cable address: ATOMICS.

ATOMICS INTERNATIONAL
A DIVISION OF NORTH AMERICAN AVIATION, INC.
PIONEERS IN THE CREATIVE USE OF THE ATOM

Other offices in: Washington, D.C., U.S.A.; Geneva, Switzerland. Affiliated with: INTERATOM, Bensberg/Cologne, Federal Republic of Germany and DYNATOM, Paris, France.

PLANNAIR GAS CIRCULATION BLOWERS FOR NUCLEAR PROJECTS

Re-affirming their leadership in matters of forced fluid flow temperature control, Plannair are now engaged upon intensive design and development of gas circulating blowers for various nuclear projects.

Ambient pressures in which these circulators work range from normal atmospheric to 300 p.s.i. at temperatures up to 350°C . . . and the gases involved are carbon dioxide, nitrogen and helium. Pressure rises through circulators extend up to 30 p.s.i. and flows through units cover a range up to 8000 lb/hour.

Circulators are usually of the high speed motor driven type with specially designed radial impellers, motors being gas and liquid cooled.

Zero leakage is an important feature of these designs.

PLANNAIR specialists in air movement

Plannair Limited · Windfield House · Epsom Road · Leatherhead · Surrey
Telephone: Leatherhead 4091/3

PLA30

Tick No 87 on reply card for further details

WIN THE BATTLE OF THE BURR..

..BY USING **Morrisflex Hammond**

BUILT UNDER LICENCE FROM
HAMMOND MACHINERY BUILDERS INC. U.S.A.

B. O. MORRIS LTD. • BRITON ROAD • COVENTRY
Telephone: 53333 (PBX) Telegrams: MORISFLEX, COVENTRY.

take NEWTHERM on test!

Test its STRENGTH

NEWTHERM is unusually strong and rigid—a feature of special importance in the larger, more vulnerable sections. Put a sample section or slab on part of your plant and *prove for yourself* its outstanding ability to withstand impact and water damage. See how it withstands rough handling in transit and erection, minimising breakage in shipment and erection by unskilled labour at the most remote sites.

Test its MOISTURE RESISTANCE

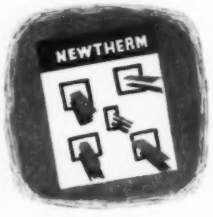
Even totally immersed in water, NEWTHERM retains much of its strength and rigidity. It does not become deformed when in contact with water, thus work-in-progress need not be covered. Especially on contracts where weather conditions would delay the application of insulation – NEWTHERM is the material to use.

Test its LIGHTNESS

Unusually light for such a high-efficiency material, NEWTHERM compares favourably in this respect with other insulants far inferior in strength. That means easier handling and fewer breakages—even the largest section is easily carried in one hand.

Test its EASE OF APPLICATION

Undoubtedly, NEWTHERM is one of the easiest of materials to apply. It is supplied in plastic form and in a wide range of standard-sized sections and slabs, smoothly finished and straight edged for immediate fitting. The finished job is very neat, with minimum joints, and appliers particularly appreciate the handleability of the material – especially in difficult situations.



READ ALL ABOUT NEWTHERM

in a specially prepared booklet. Sizes, compressive strength, thermal conductivity,—this and much more useful information can be on file if you write for your copy now, to the sole manufacturers Newalls Insulation Co. Ltd.

NEWALLS (Reg'd Brand)

***NEWTHERM** calcium silicate insulation*

. . . for temperatures up to 1400°F.

NEWALLS INSULATION CO. LTD.

Head Office: WASHINGTON, CO. DURHAM, ENGLAND.
A member of the TURNER & NEWALL ORGANISATION
Offices & Depots at: LONDON, GLASGOW, MANCHESTER, NEWCASTLE UPON TYNE, BIRMINGHAM, BELFAST, DUBLIN, BRISTOL & CARDIFF.
Agents and Vendors in most markets abroad.

STEWARTS AND LLOYDS LTD.

ANNOUNCE THE FORMATION OF THEIR

PIPEWORK ENGINEERING DIVISION

PROVIDING UNDER SEPARATE MANAGEMENT
A QUICK AND EFFICIENT SERVICE
TO THE MANY USERS
OF MANIPULATED PIPEWORK

In alloy or carbon steel,
for high or low pressure,
designed or to customer's drawings,
erected on site if required

FOR FURTHER INFORMATION APPLY TO:

STEWARTS AND LLOYDS LTD.,
PIPEWORK ENGINEERING DIVISION

BROAD STREET CHAMBERS
BIRMINGHAM 1

41, OSWALD STREET
GLASGOW C.1

PED

ALL ENQUIRIES FROM THE OIL REFINING AND PETROCHEMICAL INDUSTRIES SHOULD CONTINUE TO BE ADDRESSED TO OIL DEPARTMENT, 8 GOUGH SQUARE, FLEET STREET, LONDON, E.C.4

the SERCK organisation

is actively concerned in the supply of equipment and material with special application to the Nuclear Power Industry

PRIMARY AND SECONDARY SURFACE HEAT EXCHANGERS

CONDENSERS

AIR AND GAS COOLERS

CONDENSER TUBES

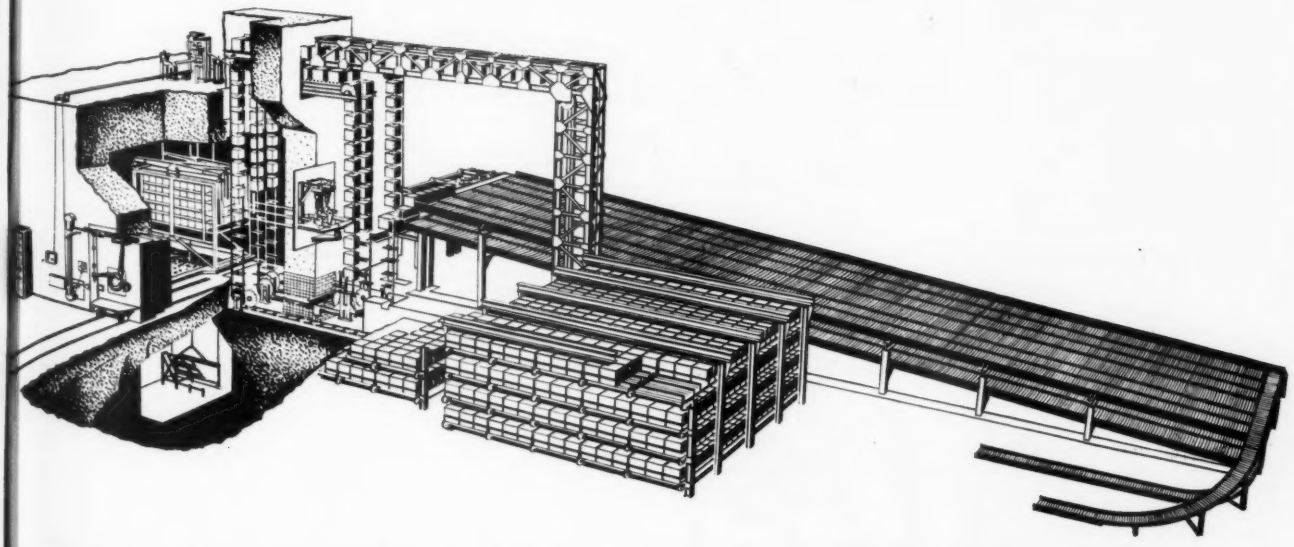
SERCK RADIATORS LIMITED

SERCK TUBES LIMITED

Warwick Road, Birmingham 11

Package Irradiation Conveyor Plant developed in co-operation with the U.K.A.E.A. by

The Owen Organisation

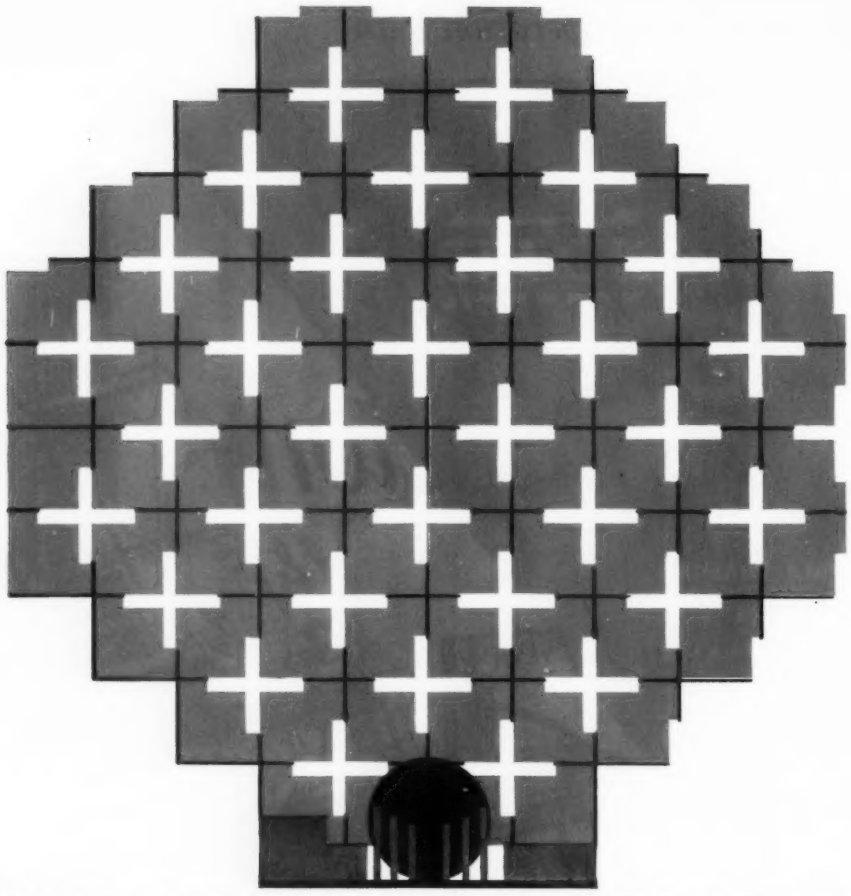


The resources of the Owen Organisation are co-ordinated to serve the Nuclear Industry in Design, Development and Manufacture.

Argonarc Welding · Rowenarc Welding · Hydraulic and Pneumatic Actuating Systems and Valves · Design and Research Facilities · Prototype manufacture facilities · Production Facilities · Patented Copper free brazing for steel stainless steel, Niobium, etc · Fork Trucks and Materials Handling Equipment · Pressure Vessels · Test facilities, including Hydraulic Pneumatic, Mechanical · Test facilities for Prototypes · Structural Steel work · Metal Equipment, Partitioning, Bins and Furniture · Remote Control Equipment · Cold and Hot Presswork · Fabrication work · High Tensile Bolts · Package Irradiation Plants · Electro-Hydraulic Controls and Servos · Special Purpose Machinery and Machine Tools · Compressors · Oil Firing Equipment

THE OWEN ORGANISATION GROUP ATOMIC ENERGY OFFICE
P.O. BOX No. 24 · WARRINGTON · Telephone WARRINGTON 35241

Tick **No 92** on reply card for further details



YANKEE ATOMIC ELECTRIC POWER STATION

USING 1,750,000 MALLINCKRODT URANIUM FUEL PELLETS

This reactor, as well as those of Commonwealth Edison Company and Consolidated Edison Company, depends upon commercially produced nuclear fuels. The uranium loading of all three will be entirely or in part Mallinckrodt processed UO_2. ◆ As the roster of reactor projects grows . . . so does the number of Mallinckrodt nuclear customers. Whether power, propulsion or experimental—domestic or overseas—Mallinckrodt has unequaled experience in producing nuclear fuel materials. ◆ Mallinckrodt's new automated pellet plant is producing about half of the UO_2 pellets (3.4% enriched) for the 134,000-kilowatt reactor of Yankee Atomic Electric Company. ◆ Mallinckrodt now offers more than 15 forms of uranium compounds and metal . . . and can deliver completed fuel elements by working with metal fabricators. ◆ For consultation on nuclear fuel problems, write or call Mallinckrodt.

MALLINCKRODT NUCLEAR CORPORATION • ST. LOUIS 7, MO.

THE WORLD'S FIRST AND LEADING PRODUCER OF NUCLEAR FUELS

BUILD YOUR EFFICIENCY WITH

OSBORN PRODUCTS

Integrated experience from over a century of craftsmanship has made the name of *Osborn* world-famous as a hallmark of quality in the manufacture of fine steels and steel products.

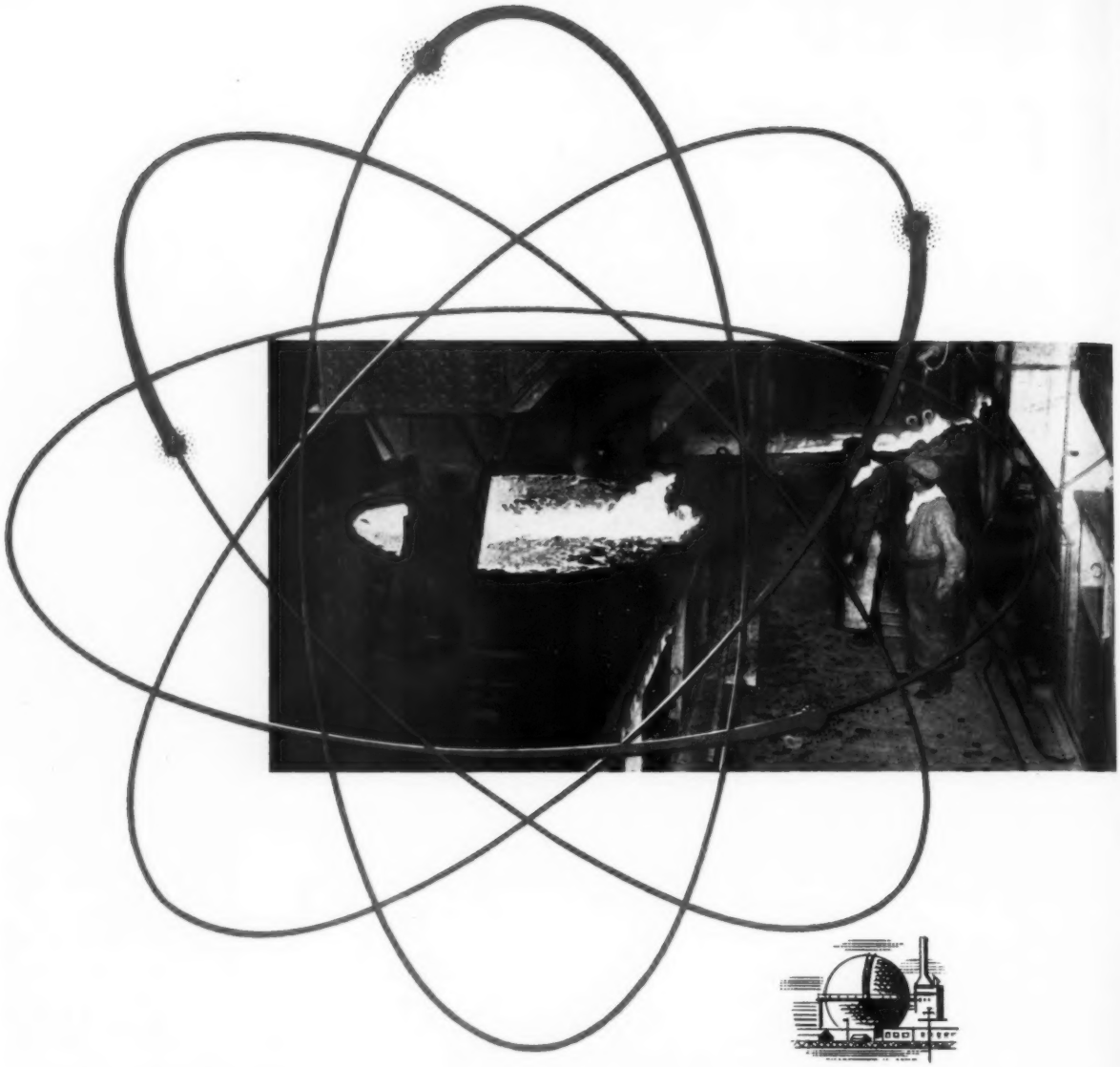
Products in alloy, stainless and tool steels are manufactured throughout within the same organisation, and include castings by general foundry and precision methods, forgings and engineers' cutting tools.

STEELMAKERS · STEELFOUNDERS · ENGINEERS' TOOLMAKERS

SAMUEL OSBORN & CO., LIMITED

CLYDE STEEL WORKS, SHEFFIELD

Tick **No 94** on reply card for further details



Specially developed steels — for the nucleonics industry

Colvilles pride themselves in being abreast of every development in the nuclear field. Their range of Special Steels has been developed to that purpose.

DUCOL W.30	ABRAZO	COLMO	COLCLAD	CORTEN	COLTUF
High Tensile Weldable Steel	Abrasion Resisting Steel	Creep Resisting Steel	Stainless Nickel & Monel Clad Steels	High Strength Corrosion Resisting Steel	Notch Tough Steel

COLVILLES

FITNESS FOR PURPOSE STEELS

COLVILLES LTD 195 West George Street Glasgow C.2

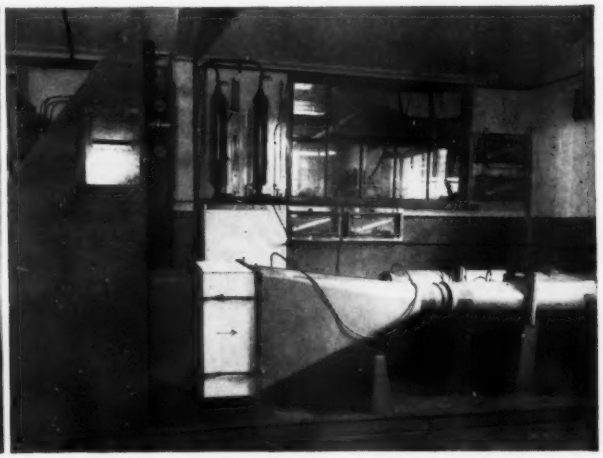
VOKES 'ABSOLUTE' FILTERS for the arrestation of toxic particles

Vokes 'Absolute' filters have been developed for applications where radioactive and other toxic dusts may be encountered, and an extremely high degree of efficiency is therefore required. The filters have a guaranteed efficiency of at least 99.95% against particles in the 0.1 to 0.5 micron range, each panel being individually tested against a methylene blue dust cloud. Unlike many filters of this efficiency, the Vokes 'Absolute' is compact and light weight and the use of a special paper medium combined with an absence of metal parts facilitates the disposal of a contaminated panel.
Special variations of the 'Absolute'—High Humidity, High Temperature, Flameproof and High Acid Resistance types—use a glass paper medium with *an efficiency as high as* 99.99%.

Please write for further details.

A bank of Vokes 55 'Absolute' filters specified by the Ministry of Works for the ventilation plant (Extract) in the High Activity Materials Handling Building, Harwell. Vokes 44 'Absolute' panels are used on the intake.

A pressure-suited operator changing a filter in the ventilation system of the G.E.C. beryllium laboratory at Erith, where beryllium dust if not trapped could endanger human lives. Other Vokes filters are fitted to equipment used in the laboratory.



The methylene blue test rig—part of the equipment in the large Vokes filter laboratories at Henley Park. Guaranteed performance figures are stencilled on each filter case.

VOKES

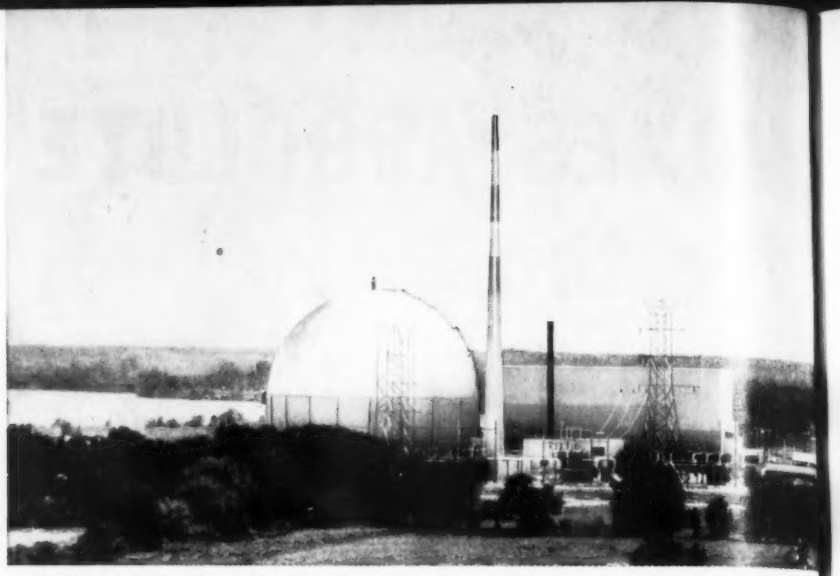
VOKES LTD · HENLEY PARK · GUILDFORD · SURREY

Tel: Guildford 62861 (6 lines) Telegrams & Cables: Vokesacess, Guildford, Telex. Telex: 13-535 Vokesacess, Gfd.

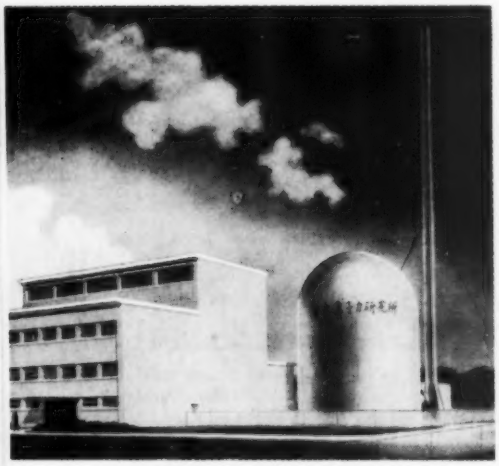
Vokes Australia Pty. Ltd. Sydney. Represented throughout the World.

V528

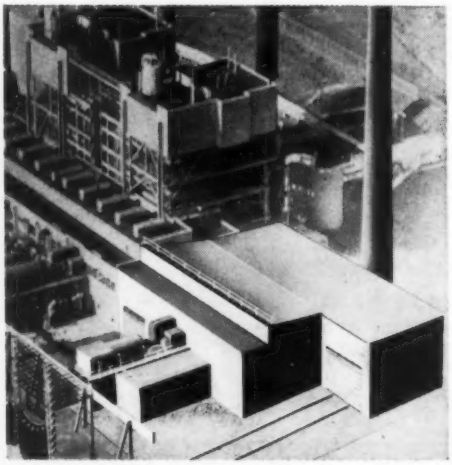
Here is evidence of General Electric accomplishment in the nuclear field. All over the world the G-E installations illustrated here are in operation or are in design and construction stages.



The Dresden Station, the nation's first full-scale, all-nuclear power station, achieved criticality on October 15, 1959, six months ahead of schedule. This 180,000 kw nuclear plant is expected to be producing enough electricity before the end of 1960 to supply the needs of a city of 200,000 people. Commonwealth Edison's Dresden Station, located near Chicago, utilizes the G-E dual-cycle boiling water reactor (BWR).

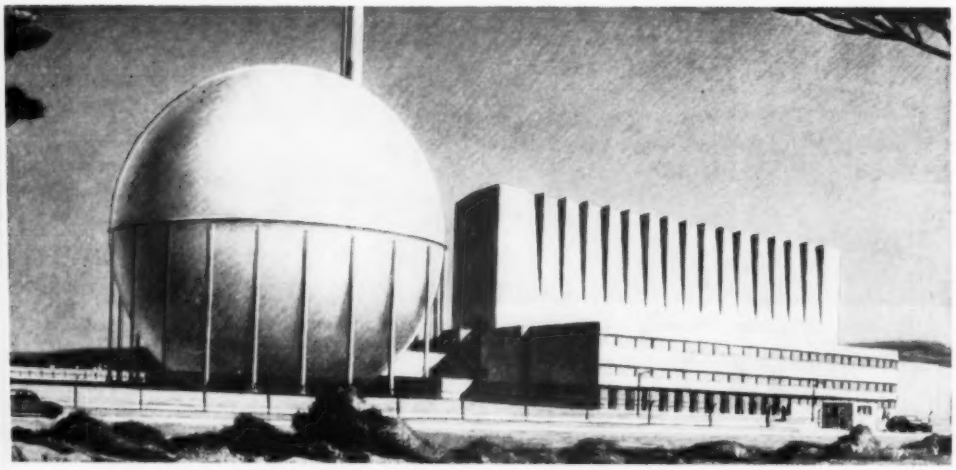


In Japan, the Japan Atomic Energy Research Institute (JAERI), selected a General Electric BWR for its 12,500 kw nuclear plant. It is expected to be the first nuclear power plant in operation in the Far East.



General Electric will furnish the nuclear steam supply system for the new 50,000 kw Humboldt Bay Plant near Eureka, California. This is the largest single-cycle, natural circulation reactor system yet planned for construction.

In Kahl, Germany, this G-E 15,000 kw BWR—Germany's first nuclear power station—is nearing completion. RWE and Bayernwerk (A.G.), joint owners of the Kahl plant, expect it to be in operation late in 1960.



Near Naples, Italy, the 150,000 kw Garigliano Nuclear Power Plant now under construction for the Societa Elettronucleare Nazionale (SENN) will utilize a G-E dual-cycle boiling water reactor. It is scheduled for completion in 1963. The General Electric BWR plant, chosen over eight other designs from three countries, was judged best all around in economics, soundness of design and development potential. Design of the plant will allow for possible increase of kilowatt output without major reactor changes.

Near the University of Madrid, a 3000 kw(t) open pool research reactor, Spain's first, was put into operation in October 1958. Twelve other G-E research reactors are operating or are under construction.

Here's The Latest Global Report On General Electric's Widespread Activities In The Nuclear Field

In Power Reactors...Research Reactors and other atomic products ...General Electric leads the way to greater accomplishment

Long identified as a leader in atomic development, General Electric is engaged in a widely diversified program of nuclear applications. The full scope of nuclear products and services offered includes reactors for power generation and marine propulsion, research and test reactors, fuel element fabrication, reactor sub-systems and auxiliaries, special engineering studies, applied research and development services and irradiation services.

General Electric has been selected to build power and research reactors on four continents, and many of these installations are shown on these pages. G.E. was awarded these reactor orders because of established reputation for success and traditional leadership in technological developments, and because: 1. it is expected that the G-E boiling water reactor will provide the lowest power costs of all the current reactor concepts; 2. the simplicity of the system makes lower capital investment possible, and 3. the Company's advanced research and development of the design and manufacture of oxide fuel elements enables G.E. to guarantee high fuel burn-up levels.

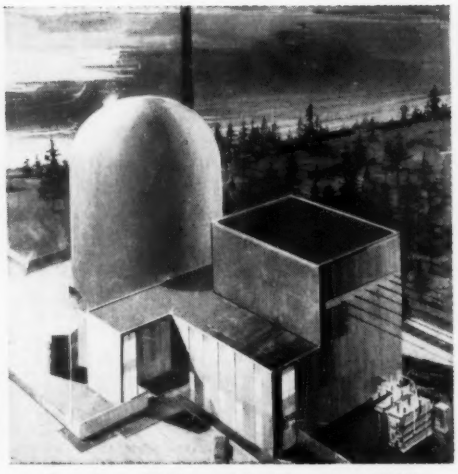
Let General Electric's extensive atomic facilities and experience in the nuclear power field help you in the application and technical advancement of atomic energy. For a copy of General Electric's latest Atomic Progress Booklet or more information about specific phases of atomics, write: *International General Electric Co., Dept. 30-14, 150 East 42nd Street, New York 17, New York, U.S.A.*

Progress Is Our Most Important Product

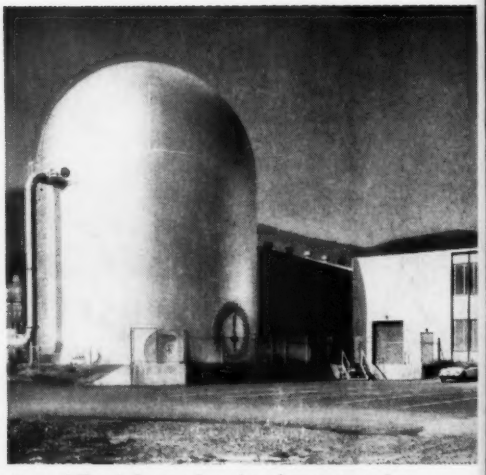
GENERAL ELECTRIC

—U. S. A.—

This G-E test reactor, 30,000 kw(t), is located at the Company's Vallecitos Atomic Laboratory in California. The GETR is being used in G.E.'s program for the development of nuclear fuels and materials.

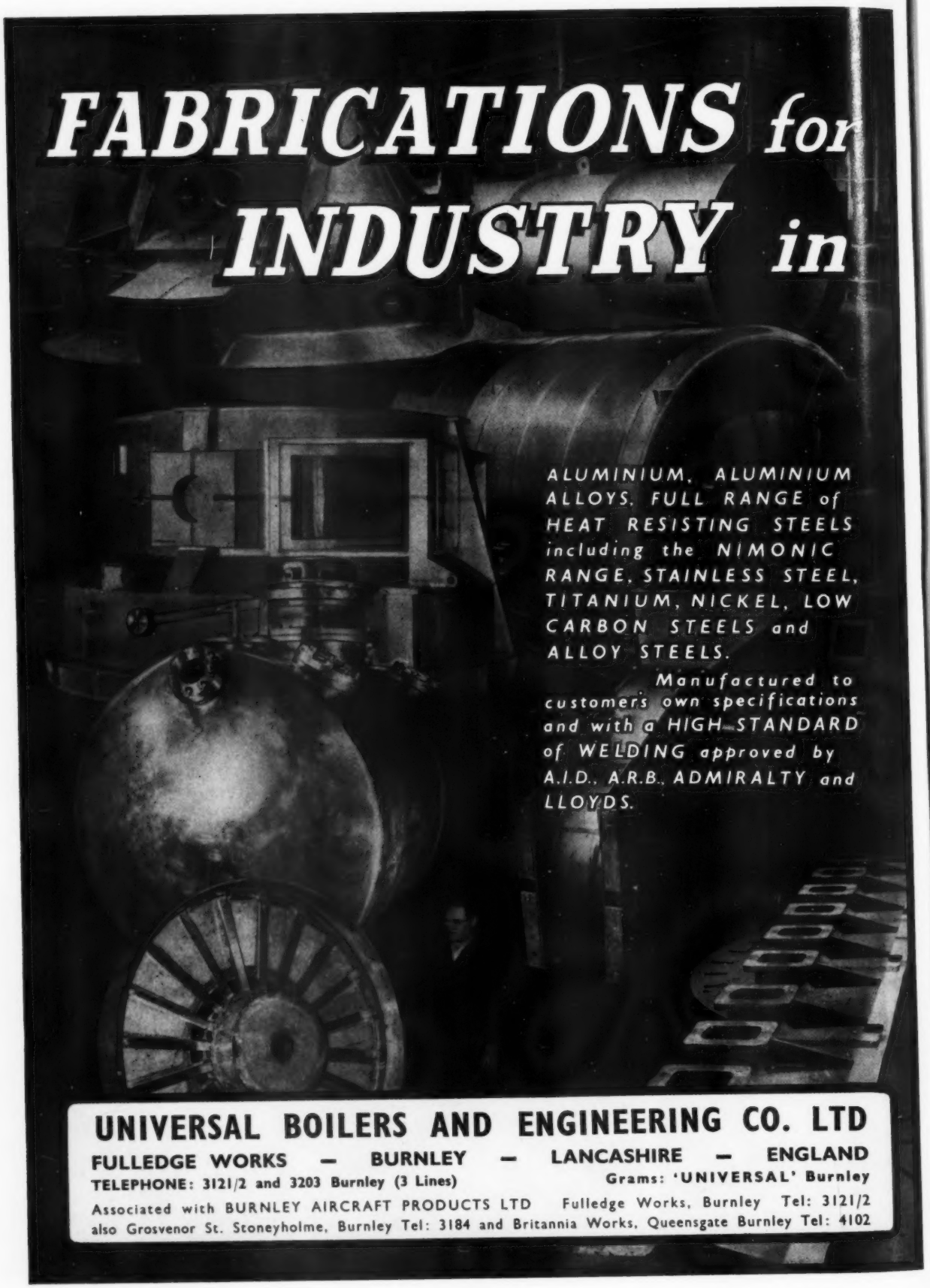


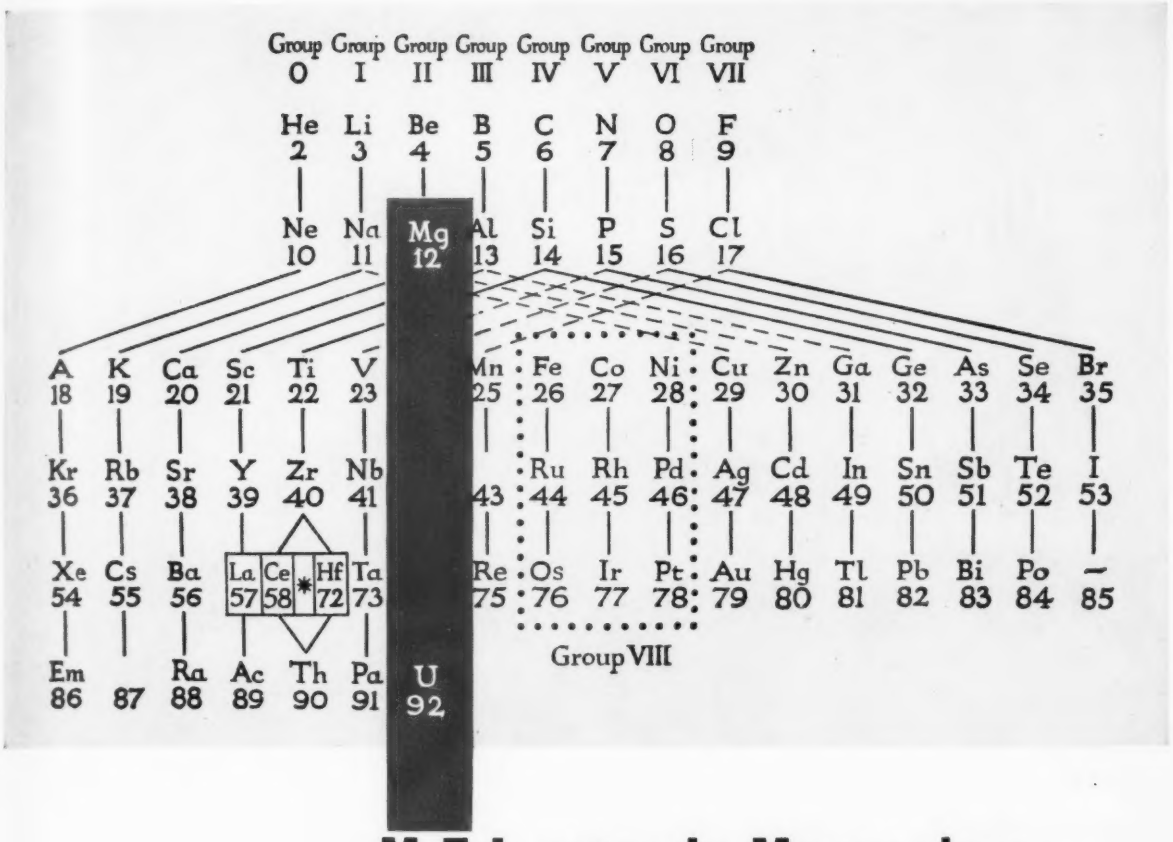
In Jackson, Michigan, G.E. will supply a 50,000 kw high specific power, high power density BWR reactor for this new Consumers Power Co. plant. Scheduled for completion in 1962, it is expected eventually to produce 75,000 kw.



General Electric has made major advances toward providing nuclear power at significantly lower costs, as a result of the operating experience gathered at its Vallecitos Atomic Laboratory which includes this 5000 kw BWR power plant, supplying power since 1957.

Tick **No 98** on reply card for further details


FABRICATIONS for INDUSTRY in
ALUMINIUM, ALUMINIUM ALLOYS, FULL RANGE of HEAT RESISTING STEELS including the NIMONIC RANGE, STAINLESS STEEL, TITANIUM, NICKEL, LOW CARBON STEELS and ALLOY STEELS.
Manufactured to customers own specifications and with a HIGH STANDARD of WELDING approved by A.I.D., A.R.B., ADMIRALTY and LLOYDS.
UNIVERSAL BOILERS AND ENGINEERING CO. LTD
FULLEDGE WORKS — BURNLEY — LANCASHIRE — ENGLAND
TELEPHONE: 3121/2 and 3203 Burnley (3 Lines)
Grams: 'UNIVERSAL' Burnley
Associated with BURNLEY AIRCRAFT PRODUCTS LTD Fulledge Works, Burnley Tel: 3121/2
also Grosvenor St. Stoneyholme, Burnley Tel: 3184 and Britannia Works, Queensgate Burnley Tel: 4102



M.E.L extends Magnesium

into the Nuclear scheme of things

There is nothing *periodic*
about research at M.E.L, where work is *constantly*
directed towards the advancement of magnesium—
especially in the nuclear industry.

Magnesium Elektron Limited are world-wide authorities
on the technology of Magnesium.
In collaboration with U.K.A.E.A
they evolved MAGNOX.
They have also originated some of
the world's finest ultra-light alloys.
Their experience is available to all who wish
to exploit the special advantages of Magnesium
in nuclear engineering.

Magnesium Elektron Limited

Clifton Junction Manchester Swinton 2511
London Office: 5 Charles II Street St. James's SW1
Magnesium Elektron, Inc. New York 20 USA

Tick **No 100** on reply card for further details

NOW manufactured in the UNITED KINGDOM

ASHCROFT 1850 U.S.A.

DURAGAUGES

Specially designed for the most exacting operating conditions in the Oil Refining and Chemical Industries, these Gauges have become standard equipment in many plants throughout the World.

PRESSURE-VACUUM
OR COMPOUND TYPES
Manufactured by DEWRANCE
under exclusive licence
Full details on request

DEWRANCE
AND COMPANY LIMITED

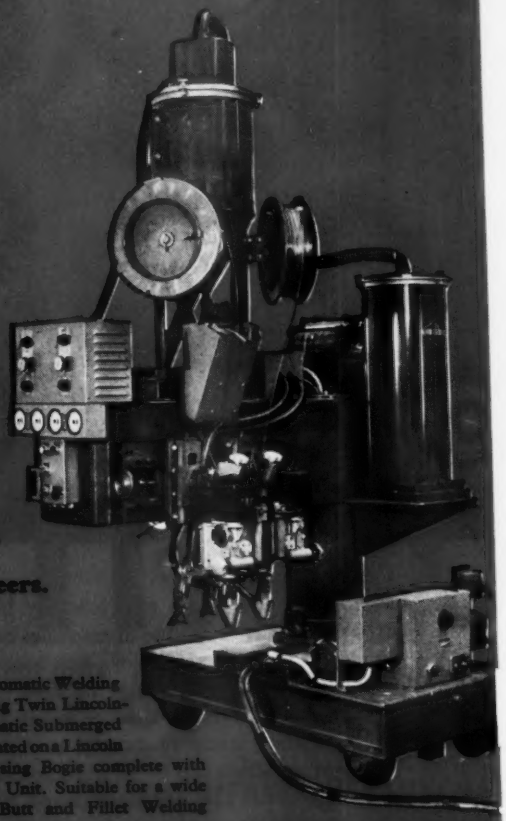
GREAT DOVER STREET, LONDON, S.E.1.
Telephone: HOP 3100 Telegrams: DEWRANCE LONDON

WORKS: LONDON · BRADFORD
DUMBARTON · HILLINGTON

DON'T SPEND MONEY—MAKE MONEY WITH LINCOLNWELD

A Lincoln Fully Automatic Mass Production Welding Installation fitted with two Lincolnweld Type B.10 Submerged Arc Welding Heads operating on controlled automatic time cycle, complete with automatic component clamping, adjustable for both length and diameter. This unit has many applications in the automotive and allied industries.

Complete welding installations by LINCOLN



Sooner or later **YOU** will become interested in Submerged Arc Welding.

LINCOLN have a *complete* range of Submerged Arc Welding Equipment PLUS

★ **Hundreds of successful installations.**

★ **Years of knowledge acquired throughout the world.**

★ **A fully trained staff of Design and Welding Engineers.**

A complete Lincoln Automatic Welding Installation incorporating Twin Lincolnweld B.10. Fully Automatic Submerged Arc Welding Units mounted on a Lincoln Variable Speed Traversing Bogie complete with built-in Flux-Recovery Unit. Suitable for a wide range of Downhand Butt and Fillet Welding Applications, of any length.

Let Lincoln be **YOUR** *Welding Consultant.*

Please write to:
The Automatic Division

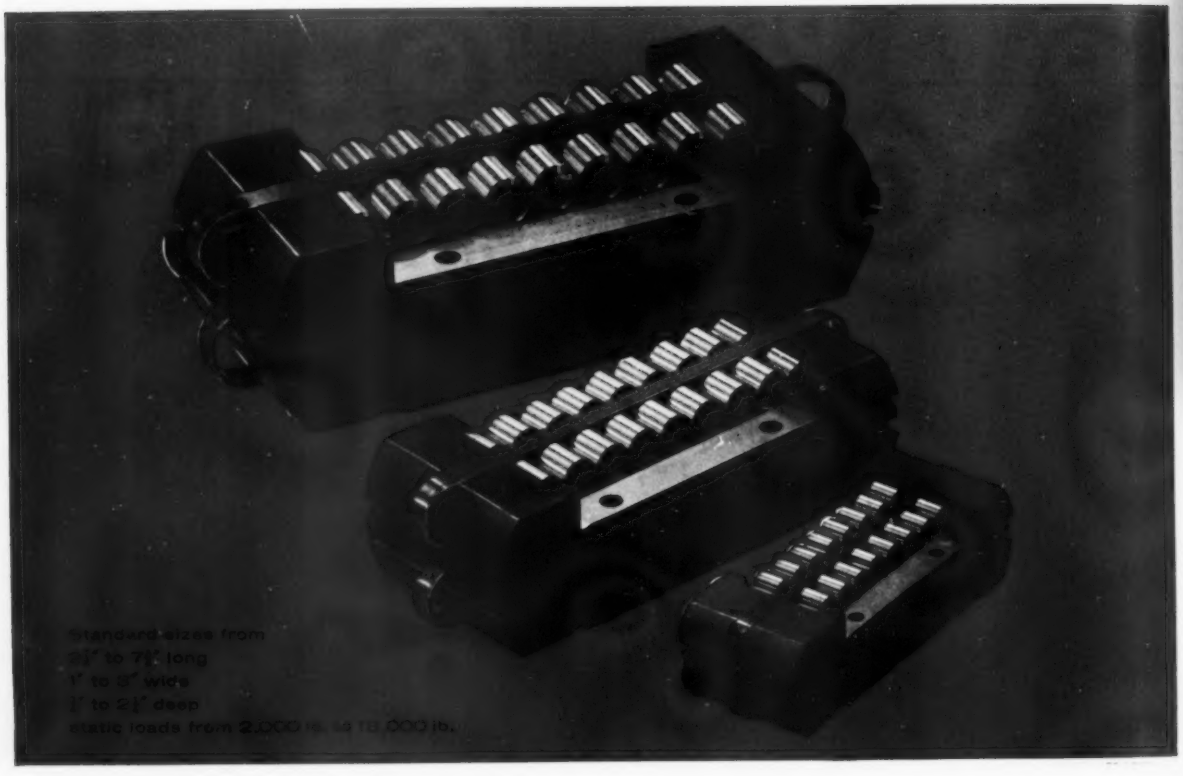
LINCOLN ELECTRIC CO LTD WELWYN GARDEN CITY · HERTS
Tel: Welwyn Garden 920 (5 lines) 4581 (5 lines)

GKN

Tick **No 102** on reply card for further details

NOW available from Rotax!

Tychoway Recirculating Anti-friction way Bearings



Rotax now offers you a range of Tychoway bearings, manufactured under licence, for use in machines requiring a very high degree of linear accuracy, very low friction and long accuracy life. These bearings are used throughout for machine tools. A return channel within the race provides easy, accurate assembly directly to a precision machined flat surface which can be supplied to customers specification if required. This eliminates hand fitting of the slides. Way wipers can also be supplied. Centre guided rollers end problem of skewing usually met in roller ways. All working parts are made of through hardened EN31 bearing steel to provide long bearing life and operational accuracy.

- CONSTANT ACCURACY
- ELIMINATION OF WEAR
- NO " SLIP-STICK "
- FRICTION FREE
- UNLIMITED TRAVEL
- MINIMUM LUBRICATION
- FEED POWER REDUCTION

If you would like information, on Tychoway Bearings Recirculating Ball Threads, Miniature Switchgear, Compressors, Railway Point Machines, Level-crossing Barriers, Pneumatic Motors, please write or telephone:

INDUSTRIAL GROUP

ROTAX

ROTAX LIMITED
WILLESDEN JUNCTION LONDON N.W.10. (ELGAR 7777)
LUCAS-ROTAX (AUST.,) PTY LTD., Zetland, New South Wales, Australia.
LUCAS-ROTAX LTD., Toronto 13, Ontario, Canada.

Rio Tinto is now able to supply

uranium in commercial quantities

for power and research programmes

RIO TINTO

Nuclear grade uranium products now available include the following :

AMMONIUM DIURANATE • URANYL NITRATE HEXAHYDRATE • URANIUM TETRAFLUORIDE • CERAMIC GRADE URANIUM DIOXIDE • URANIUM METAL

Facilities exist for fabrication to individual requirements.

Enquiries are invited to

RIO TINTO MANAGEMENT SERVICES (U.K.) LIMITED

Barrington House, 59 Gresham Street, London, E.C.2. Telephone METROPOLITAN 9101

Safe Conduct

Tough, flexible, seamless, all-metal PLESSIFLEX is the most thoroughly reliable means of conveying fuels and chemicals—whether they are gases or liquids, very hot or very cold, corrosive or inflammable—from one place to another. And this point is overwhelmingly endorsed by engineers in the aeronautical, nuclear, marine and chemical industries.

At pulsing pressures, at high pressures or under vacuum conditions, PLESSIFLEX provides the vital link between those parts in your installations which are subject to continual relative movement.

The basic components of PLESSIFLEX are the result of continuous development and testing, in consequence of which the complete hose units are unrivalled in their high quality. Offered in a range of sizes from $\frac{1}{8}$" to $2\frac{1}{2}$" bore, and in almost any metal you care to name, PLESSIFLEX may be tailored to *your* particular requirements.
Suitably braided for stability, the tube itself is made from material that has been subjected to rigorous pre-process analysis—everything in fact about this versatile, incredibly robust product is shaped to the ends of higher performance and greater safety in fields where such requirements are essential.

A PLESSIFLEX application on the Fristol Bloodhound

Our engineers are waiting to show you how PLESSIFLEX can solve **your** piping problems

Regd. Trade Mark

POWER AUXILIARIES LIMITED · Kembrey Street · Swindon · Wilts · Tel: Swindon 6211

Overseas Sales Organisation—Plessey International Limited, Ilford, Essex Tel: Ilford 3040

PAL14c

Nuclear Power
REACTORS MATERIALS INSTRUMENTATION PROCESSES IRRADIATION

APRIL 1960 VOLUME 5 NUMBER 48

VIEWPOINTS *letters to the Editor*

Gas turbines

SIR: Your report from Hamburg on prospects for nuclear powered ships (NUCLEAR POWER, Jan. 1960, page 108) mentions the claims made by the US Maritime Administration for the closed-cycle gas-cooled reactor for ship propulsion, which seem over optimistic.

'*Efficiency can be maintained over 50 to 100% load range*'. This could be approximately true if the pressure levels in the circuit be altered to suit the shaft power required and if the compressor speeds can also be altered to suit the pressures and compression ratios required. The power turbine must, of course, run on the propeller law. The diagram shows the high and low pressure compressors on the same shaft and tied to the auxiliary generator so that they presumably have to run at constant speed to keep the voltage correct. Efficiency cannot, therefore, be maintained through the load range, as the power and compressor turbines must be mis-matched except at the design point.

'*Rapid start-up and load changes are feasible*'. This is difficult to arrange if it entails letting in more gas from storage when power is to be increased and discharging a large volume of hot gas to storage when decreasing power. Power must be changed without causing either compressor to surge. In the system shown it will be very difficult to avoid stalling some of the compressor blades, particularly with rapid change of power, and fairly easy to cause a bad surge. To prevent this blow-off may be needed between the compressors or between stages.

'*Core thermal capacity can absorb initial after-heat*'. If the core has a large thermal capacity this will act against rapid power change.

'*Simple one-fluid systems*'. The gas system shown is extremely complicated and, even so, does not include the arrangements for varying the pressure level. Keeping eight large shaft glands gas tight and preventing gas leaks in the regenerator and intercoolers will be difficult.

'*The system offers advantages in safety in that emergency cooling by air could be effected*'. If air is used for emergency cooling the graphite may burn and the results will be even more disastrous than the Windscale accident.

The gas turbine has made little progress in marine propulsion except of small craft and no closed-cycle gas turbine has ever been to sea. Nuclear heat may eliminate blade fouling, but that advantage is not enough to counter the many drawbacks of the gas turbine at sea.

It is a bird, not a fish.

CAPTAIN H. F. ATKINS
Vickers Nuclear Engineering Ltd.,
Vickers House,
Broadway, London, S.W.1

Manpower economy

SIR: I have read your editorial on men and man power in NUCLEAR POWER for February 1960 with considerable interest. While I agree with you wholeheartedly, particularly with reference to recruitment of scientists and engineers, I think that there are two factors which you have not mentioned, but which are vitally important in the industrial field in our country today. Firstly, a number of our first class scientists and technicians with a few years experience are being tempted to leave this country for work in the USA and elsewhere. Secondly, while Industry makes considerable provision for the training of young people after leaving school by allowing time off from work to attend day classes, and supports attendance at special courses etc., the number of hours of work available from these people is reduced and consequently a greater number have to be employed in order to accomplish their particular tasks. I should say that this accounts for an increase of 15–20% in numbers required.

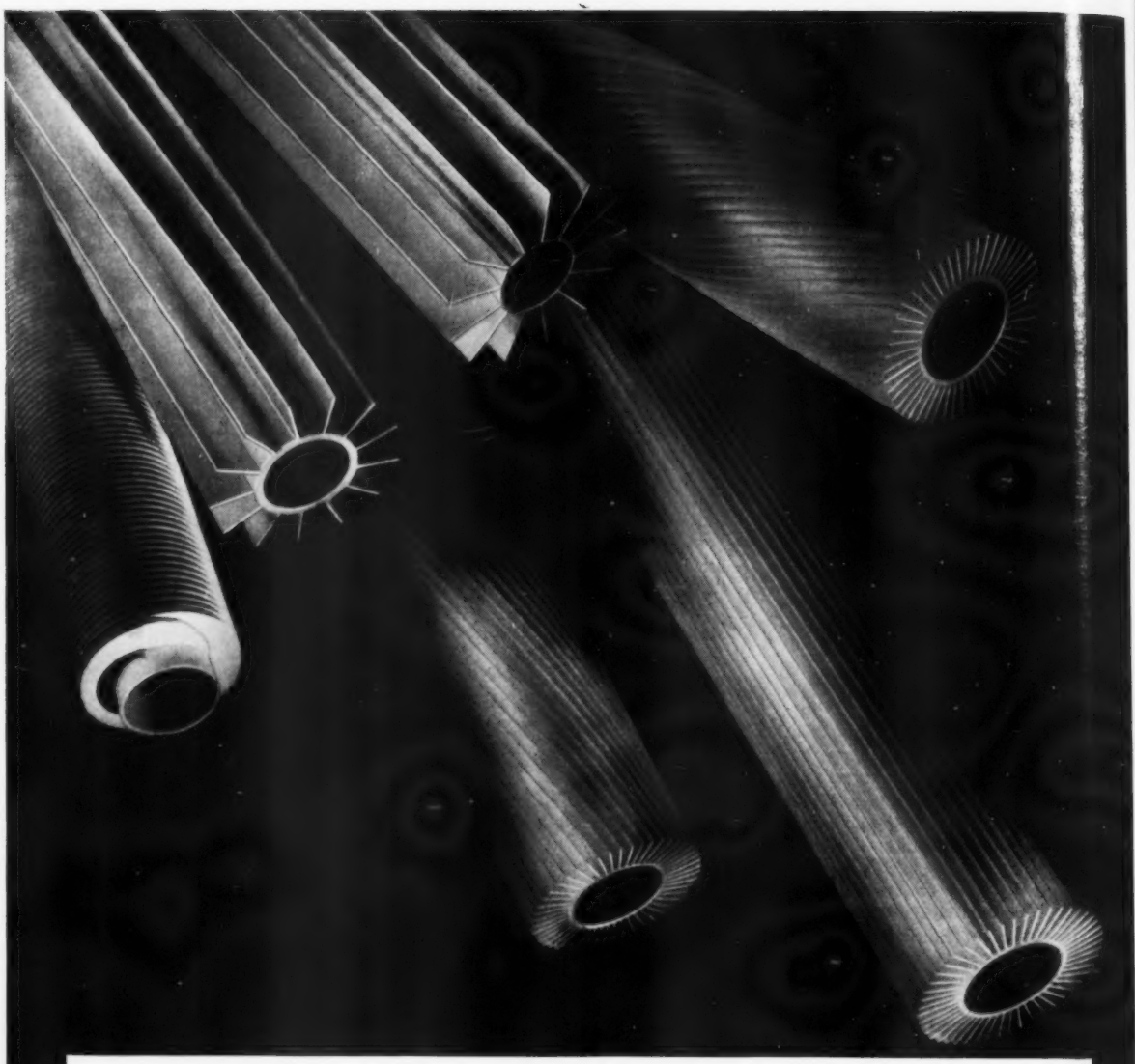
The problem of shortage of scientific and technical personnel is world wide but in view of our precarious position as a nation, which must export in order to provide food and clothing for our population and maintain our high standard of living, it is absolutely essential that the scientific and technical standards are maintained. Do not therefore let us squander our efforts by unnecessary duplication. Do not let us ignore Industrial Organizations, capable of high grade work, and do not let us undertake work in Government Establishments that can be entrusted to industrial organizations. After all Industry has to work economically in order to produce a profit and so pay the taxes to keep the Government Establishments in existence.

Chalfont St. Giles G. J. METCALFE
Bucks

PUBLISHER'S COLUMN

A foreign issue

Most of this issue is devoted to French activities. Considerable difficulties have had to be overcome in making such a review possible: long-term planning, extended negotiations with the French authorities, close cooperation with the industrial companies, and the final organization of rapid but correct translation of many thousands of words on nuclear techniques. Although we were gratified with the many encouraging comments that have arrived concerning our Tokai-Mura presentation in last month's NUCLEAR POWER, and with the additional orders for the coloured drawing, we have attempted to improve the pictorial appearance of our EDF2 drawing in this issue even further by using a better quality paper specially obtained.



Tomorrow's metals-today

The demand for new and still newer metals is nowhere more clearly seen than in the requirements of nuclear engineers for fuel sheathing materials. In a few years, the range of metals used for 'canning' has expanded to cover specially developed aluminium and magnesium alloys, zirconium, niobium, vanadium and beryllium.

I.C.I. specialises in all these nuclear metals—and is Europe's largest producer of wrought titanium, the first 'new' metal to come into full commercial production. With zirconium output also at a commercial level, I.C.I. Metals Division is now operating the first production scale wrought beryllium plant in Europe.

first in nuclear metals

IMPERIAL CHEMICAL INDUSTRIES LIMITED, LONDON S.W.1

ICI METALS DIVISION

OPINION

Subsidize nuclear ships

THERE IS NOTHING at the moment to prevent any country from sending a nuclear-propelled ship to sea and there is absolutely no provision to safeguard the lives of the thousands of people who might be affected by radioactivity released in a serious marine accident. Visits are being made to this country by American nuclear submarines and later there will be the proving tests of the two nuclear surface vessels *Savannah* and *Lenin*. Public misgivings are only natural even if they are a little premature at the moment, but this is not the time to wait until the vessels are ready to sail before making proper international regulations.

The results of the Yugoslav meeting of the International Maritime Committee last September were not exactly encouraging. They met to frame a convention dealing with liability for nuclear damage to persons and property caused by an atomic ship but few of the delegates had much, if any, knowledge of the science of marine nuclear propulsion. It is to be hoped that the IAEA Panel on nuclear ship hazards that has just concluded its business will have tidied up the problems left over.

At such a moment, it was more than encouraging therefore to read the recommendations of UK Committee on Nuclear Ship Safety. The report should carry weight, too, because of the Committee's representation which included, apart from the appropriate Government departments, the shipping industry, employer organizations, port authorities, classification societies, the shipbuilding industry, research associations and the Atomic Energy Authority. Greater encouragement will be given to the five companies who are preparing tenders for the first UK nuclear merchant vessel, now that the Government's attitude to marine design has been declared.

Nuclear ships are in most circumstances to be treated as ordinary surface vessels but with certain reasonable design and navigational safeguards. The critics who thought that the safety control systems proposed for the BWR and OMR designs were too elaborate and far too costly, whilst they might have been right according to their own standards, have now been shown that until nuclear ship operation has been proven, absolute safety is the all important design feature to aim at and this involves elaboration at the moment. Confidence in the ability and skill of the scientists and engineers concerned with the design and development of nuclear reactors was reflected by the committee and it comes at a time when appeals are being made for speedy Government assistance to Britain's shipping industry to build up its competitive strength.

In its annual report, the Chamber of Shipping did not think that the Government should expect the industry, in the midst of its present difficulties, to undertake the vast amount of research into nuclear propulsion that is required. And what of the firms who submitted designs to the Galbraith Committee? The efforts involved have represented considerable outlay particularly for the designers of the steam cooled heavy water moderated, pressurized water, and advanced gas-cooled systems, which have not been selected. The five companies who are tendering for the two accepted types are going to be involved in even greater expenditure and only one of them is to be given the contract for further work and, from the experience already gained on building land based reactor stations, this is not likely to result in profit to the company concerned.

The official attitude to air transport research, with vast government sums allocated and promised should be applied equally to research into nuclear propulsion. The Government cannot have it both ways; industry is capable of tackling the difficult tasks ahead but it needs, more than anything, not platitudes but financial support.

French industry

TREATING INDUSTRY right does not seem to be a problem in France; our survey of the nuclear scene there this month indicates that private enterprise operates far more closely with the government in all its projects and enjoys a greater share of nuclear activities. This close cooperation extends also to Electricité de France, the French equivalent of the UK Central Electricity Generating Board, whose activities and influence extend beyond metropolitan France to Africa, Madagascar and South America.

France started off at a great disadvantage after the war but it is fortuitous that this late start, coupled with the improved position in conventional fuels, has enabled her to go more slowly on power reactor development and to have a 'new look' at conceptions other than the gas-cooled type before it became too immersed. It is significant that M. Couture of the CEA, who spent several weeks recently in Canada and USA, showed considerable interest in Canada's heavy water programme.

The 100 MW EL4, construction of which is to start this year at Marcoule, is a natural uranium gas-cooled reactor but it will use heavy water as moderator. The carbon dioxide-graphite system will go on but other concepts are not being neglected. High temperature research is to be made at Cadarache, the new nuclear research centre, particularly on the use of gas turbines for electric power production, in addition to experiments on the liquid sodium cooled fast breeder.

Power-made to measure!

The ever-increasing demand for electricity must be met and, if this country is to survive as a prosperous and expanding industrial nation, it must be met as economically as possible.

The problem is being solved in two ways—by increased technical efficiency in normal power station operation and by development of nuclear power. New power stations, whether they burn coal or depend on nuclear energy, are progressively more and more efficient.

Coal will long continue to be our main source of power. The present surplus is only temporary.

In the foreseeable future the expanding demand for power will exceed the available supply of home-produced coal. That is why Britain has a nuclear power programme which is the largest and most progressive in the world.

C·E·G·B

THE CENTRAL ELECTRICITY GENERATING BOARD

Worldview

the month in atomic energy

Consortia merger splits: APC and GEC part

After several months of trying to turn their collaboration agreement into a workable organization, Atomic Power Constructions and the GEC-Simon-Carves Group have agreed to differ. The original idea (*Worldview*, November 1959, page 85) was to merge the two concerns more or less completely and submit joint tenders for Dungeness and future nuclear power stations, as well as combining their research efforts; but when it came to detailed arrangements the two groups found their attitudes irreconcilable.

The official viewpoint, as stated by a spokesman for Atomic Power Constructions, is that it was 'just not possible to find the formula for an organization which would give effective control of any contract which might be awarded to a joint undertaking.' Having found that they do not talk the same language, the two groups have parted company completely. Atomic Power Constructions has sent in its bid for the Dungeness Station. The GEC will not be tendering for this; it has decided to concentrate on the next —Sizewell—instead. Meanwhile the other consortia link up (The Nuclear Power Plant Co. and AEI-John Thompson) seems to be functioning smoothly under its new title, The Nuclear Power Group.

Japan agrees to buy Tokai-Mura fuel

The 'Heads of Contract' agreement for the supply of fuel for the nuclear power station to be built at Tokai-Mura in Japan by the General Electric Company Ltd. of England (NUCLEAR POWER, March) has now been signed. Taking part in the ceremony were Sir Roger Makins, Chairman of the United Kingdom Atomic Energy Authority, and Mr. Daigoro Yasukawa, President of the Japan Atomic Power Company.

The main features of the detailed contract, which will govern the supply of new fuel and the purchase of irradiated fuel during the first ten years of operation have apparently been established, though according to Dr. R. Sagane, the President's top adviser, prices have not yet been fixed. 'We have come to an overall understanding on guarantees and prices', he told NUCLEAR POWER, 'but detailed figures will not be established much before the signing of the actual contract in early 1962'. Total price for the initial charge of about 200 tons is, however, expected to be something over £3 million. Dr. Sagane went on to say that the first charge would certainly be sent back to the UK for re-processing but there is room in the inter-governmental agreement for other courses in future. The possibility of buying future fuel supplies for the reactor from other countries is also not excluded.

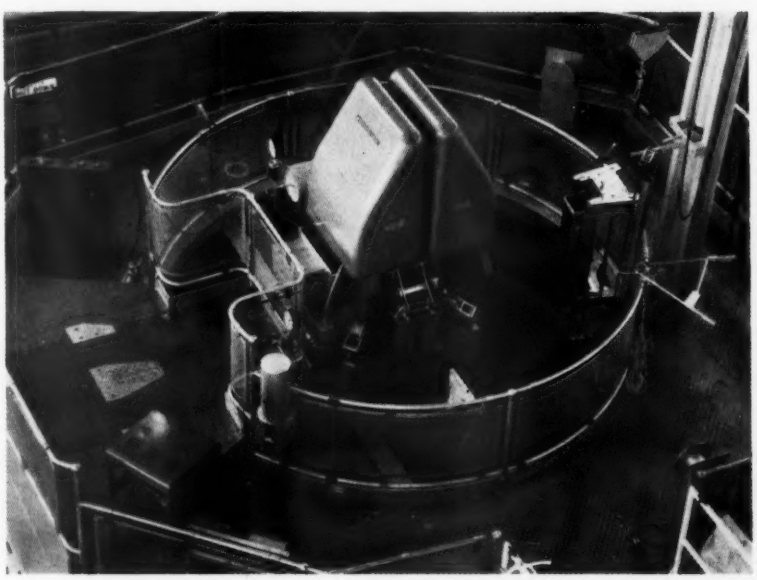
Holland buys UK reactor

The Dutch Nuclear Research Centre (Reactor Centrum Nederland) is to buy a 10 kW Jason research and training reactor from the Hawker Siddeley Nuclear Power Company. It will be installed at Petten, north of Amsterdam, as a complementary tool to the high flux reactor under construction there and should be in operation by next August; it will be the first small British reactor on the Continent. The cost to the centre will be £50,000, plus a similar amount for installation. The fuel—90% enriched uranium—will be rented from the US Atomic Energy Commission.

John de M. Baynham, secretary and commercial manager of Hawkers, went to the Hague recently to sign the contract with Dr. L. Kramer, Chairman of the Centre, Dr. J. J. van Rysinge, also from the Centre, and Dr. W. Reyseger, Director of the foundation. This new order follows the recent sale of a Jason to the United Kingdom Atomic Energy Authority for the Winfrith Heath Research Establishment. For a description of the Jason, including a full-page drawing, see NUCLEAR POWER, March 1959, page 91.

Herald goes critical

The new research reactor Herald at the Atomic Weapons Research Establishment at Aldermaston is now in operation. It will be used for work requiring intense neutron beams and for irradiation-damage studies on reactor materials. Herald is a light water-moderated and cooled tank-type thermal reactor designed to operate at 5 MW continuously. The core of the reactor is in the form of thin plates of enriched uranium-aluminium alloy suitably spaced in water. A high flux density of thermal and fast neutrons of the order of 10^{14} neutrons per cm^2 will be achieved. The reactor was built for the UKAEA by the AEI/John Thompson Nuclear Energy Co. Ltd., and is an adaptation of that company's Merlin reactor to an AWRE specification. Construction began in 1958, and picture (right) shows the finished plant.



US to get Dragon results

The United States will have access to the results of the Dragon Research Project under a new proposal recently approved by the Board of Management. In exchange for information about the 20 MW high-temperature reactor to be built at Winfrith Heath, the European Group will be given results from the similar Philadelphia Electric Company reactor in America. Earlier in its recent meeting, the Board approved a £2·83 million budget for 1960–61, about one-fifth of the forecast expenditure of £13·6 million for the plan's five-year period. The reactor plant and buildings will cost £950,000, off-site research and development £910,000, and £970,000 will be spent on the maintenance and work of the international staff, which will eventually number some 240. Most of them will have arrived at the site by the middle of the summer. Chief Engineer of the project is Mr. J. Franco of Euratom, appointed in succession to Mr. F. von Ritter, who died recently.

Harwell divisions reshuffled

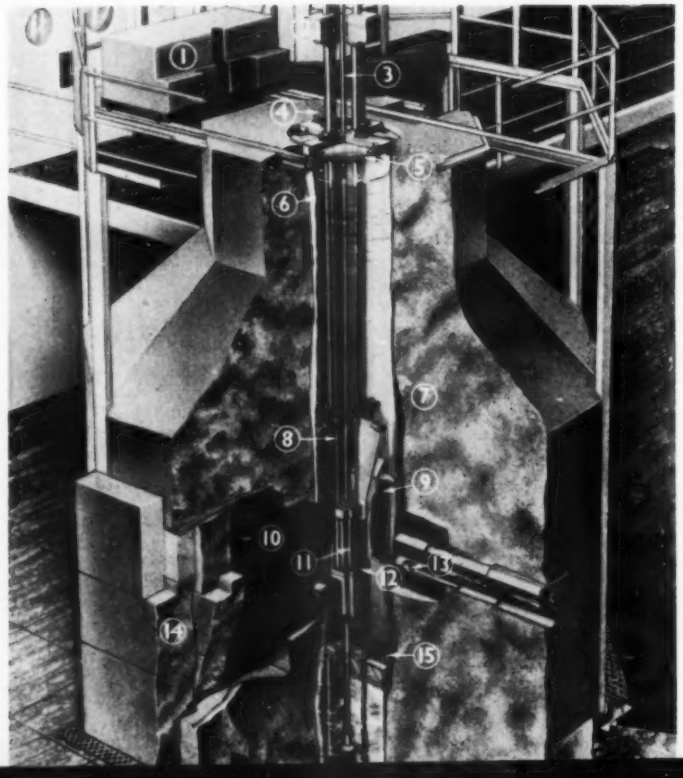
The Reactor Services Group at Harwell has been merged with the Research Reactor Group to form a new division, the Research Reactor Division. It will have responsibility for the operation, maintenance, safety, and development of Harwell research reactors and their facilities, including rigs, loops and auxiliary equipment. Physics experiments necessary for the solution of design and operational problems and studies on possible future research reactor systems will also be undertaken, led by Mr. W. F. Wood, who is acting head of division. The reorganization became necessary with the shrinking of the original groups benefiting from the moving of staff to the Winfrith establishment.

Imperial College to have all-British training reactor

The new British-designed research and training reactor, Consort, to be marketed by the General Electric Company Limited (*Worldview* March) is a 10 kW, light water moderated and cooled type, using standard LIDO enriched uranium alloy plate-type fuel elements. It was designed jointly by the GEC-Simon Carves consortium and the Nuclear Power Group at London's Imperial College. The basic scheme was originally produced for the proposed installation to be operated by the Imperial College group, headed by Professor J. M. Kay, at a convenient site outside London. Government approval for the project has been obtained in principle and it now awaits financial sanction before an order can be placed with the GEC. The cost of the reactor will be £50,000.

The main aim of the design is to achieve the ease of fuel handling associated with swimming-pool reactors with the compactness of the enclosed tank type. The core is located only ten feet below the surface of the water moderator in an open-topped tank but additional shielding is provided in the form of movable concrete-filled trolleys which cover the top of the tank while the reactor is in operation. It has been possible to incorporate an experimental 'bare-face', protected by portable shielding blocks closely adjacent to the core. With the reactor shut down, the shielding trolleys can be withdrawn and manipulation of the fuel elements carried out beneath the water under direct observation by the operator, using manual techniques.

Maximum flux available at the experimental face is 3×10^{10} thermal and 2×10^{10} fast neutrons per cm^2 for continuous operation. A similar flux can also be obtained at the inner face of a graphite thermal column on the opposite side of the tank. An optional extra is a dual-purpose thermal column which can be used to feed a vertical beam of neutrons to an experimental assembly; it consists of a horizontal column of graphite built against the bare face and having a vertical stub at its outer end. By means of suitable voids in the graphite, the neutron flux at the end of the stub may be optimized for both strength and distribution. The dual-purpose column may at the same time be used to provide a horizontal beam of neutrons if required.



Cut-away view of Consort shows: 1. Shielding trolley; 2. Control rod mechanism; 3. Vertical experimental tube; 4. Channel for water connexions; 5. Perspex dust cover; 6. Tank; 7. Biological shield; 8. Control rod; 9. Experimental face; 10. Thermal column; 11. Fuel elements; 12. Core support plate; 13. Flux-measuring instruments; 14. Concrete shielding blocks; 15. Shielding plugs for element storage holes

AUSTRALIA

Second reactor ordered

Sydney A second reactor is to be installed at the Lucas Heights establishment to supplement the 10 MW Hifar supplied by the UK. The new reactor will be a 10 kW thermal UTR-10 graphite-water moderated enriched uranium type and will be in operation by next autumn. It will be supplied and commissioned by the Advanced Technology Laboratories Division of the US American-Standard. In view of the facilities and staff already established at Lucas Heights, the extra cost will be only about £65,000.

The main functions of the UTR-10 will be to take over work requiring less flux than the high-powered Hifar. It will also be used for training future reactor operating staff. American-Standard state that they won the contract in competition with other firms both in the US and UK.

THE ROAD TO LATINA The first heat exchanger for the Latina nuclear power station leaves Anzio on the last 19-mile leg of its long journey from the Massa Apuania works of the manufacturers, Nuova Pignone. Complete itinerary was as follows: by special trailer to the shipping dock of Marina di Carrara, some 60 miles south of Genoa; each boiler was then towed 230 miles by one or two seagoing tugs to the harbour at Anzio. The heat exchangers were designed by the UK Head, Wrightson and Co. Ltd., a member-company of the Nuclear Power Plant Co. Ltd., who were responsible for the design of the complete 200 MW station

GERMANY

Government aids ship project

Bad Godesberg — The Federal Ministry for Atomic Energy has granted 1,500,000 DM to Howaldtswerke AG, shipbuilders in Hamburg, and Siemens-Schuckertwerke AG, of Enlangen, towards the cost of a study project for a marine propulsion reactor. This design study will cover a pressurized water reactor fuelled with enriched uranium oxide and a thermal output of approximately 70MW, corresponding to a power output of some 20,000 shp. Main object is to investigate the feasibility of the type and see whether it has the output efficiency credited to it by other countries. The overall project is estimated to cost some £270,000 (three million DM) of which the Government has undertaken to meet half. Further, the Ministry for Atomic Energy has recommended that the German Atomic Commission includes, in its reactor investigations and calculations, a PWR for marine propulsion and has brought the desirability of such work to the notice of the Federal Parliament.

UNITED STATES

Gas-cooled reactor starts up

Idaho The Gas-Cooled Reactor Experiment No. 1 at the National Reactor Testing Station here went critical recently. Representing the initial phase in the Atomic Energy Commission's effort to develop a mobile nuclear power plant for the army, the 2·2 MW thermal reactor is water-moderated and nitrogen cooled. It was designed, built, and is being operated for the Commission by the Aerojet General Corporation; cost so far is £M1·6. This is the first direct and closed-cycle gas-cooled reactor system to be tested. The gas, heated in the reactor core, is used to drive the turbine and is then returned to the core.

The next stage in the programme is the Mobile Low-Power Nuclear Power Plant No. 1, also being developed by Aerojet-General. It will combine the direct- and closed-cycle gas-cooled reactor system with a gas turbine driven power conversion system being developed at the Gas Turbine Test Facility in Virginia. About 400 kW of electricity will be generated and the plant should operate for at least a year at full power before re-fuelling. The entire power plant will be transportable in four packages totalling less than 38 tons.

FAR EAST

Khruschev promises reactors

New Delhi The supply of Russian reactors to both India and Indonesia seems likely following Mr. Khruschev's recent visits to the two countries. In New Delhi officials have announced India's interest in a Soviet offer to build a nuclear power station and a formal agreement of collaboration in Atomic Energy has been reached. An Indian delegation, led by Dr. Bhabha, is to visit Russia in May or June to study the design and techniques of nuclear power stations operating there.

The United States is also interested in nuclear collaboration with India and a delegation headed by the Deputy Director of the Atomic Energy Commission, Mr. B. Kratzer, is also in India to explore possibilities.

Russia's recent seven-year Economic and Technical Cooperation agreement with Indonesia provides for another £90 million of credit and may include the sale of a research reactor. Russian aid to Indonesia now totals £132 million compared with about £190 million from the United States.

INTERNATIONAL

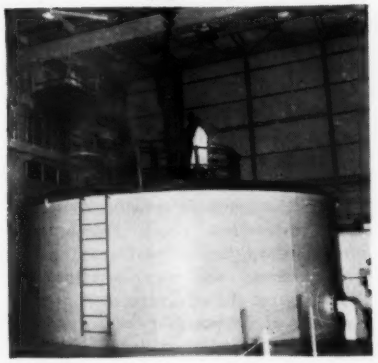
OEEC to be replaced ?

Paris Discussions now taking place between representatives of the Organization for European Economic Cooperation (OEEC) and the American Government may lead to the formation of a new group including the US and Canada with the 14 European countries. It is believed that the United States, which already has observers attached to some of the OEEC agencies, would be quite willing to integrate itself gradually into some of them without actually changing the name of the overall organization. The main objection to this comes from France which would prefer to start afresh with a new body. There is no insuperable objection to this, but the thorny problems of tariffs and discrimination have yet to be settled.

WORLDBRIEFS

• **Austria** The Atomic Energy Society has awarded a contract to the US M&C Nuclear subsidiary of Texas Instruments Inc. for the fabrication of 36 MTR-type fuel elements in the Adapted Swimming Pool Tank reactor, Astra.

WINFRITH Physicists load a fuel element into the Zenith zero energy high-temperature reactor, which is now producing data for the Dragon project (see story, page 108)



Worldview

• **Canada** Atomic Energy of Canada Ltd. and the US Atomic Energy Commission are negotiating an expanded programme of cooperation in the development of heavy-water-moderated reactors. A US contribution of £M1¼ ($M5) towards the heavy water reactors to be constructed in Canada is forecast.

• **International** The Spanish Government has offered 140 tons of uranium for sale to the International Atomic Energy Agency and its member states in 1960–62. The 1960 supplies would be in the form of sodium uranate with an average concentration of 65% uranium at a price of £7·06 per kg. In 1961–62 anhydrous uranium trioxide could be provided at £8·86 per kg of uranium.

• **Italy** The AGN 201 reactor at the University of Palermo started up recently. It will be operated by the faculty of Engineering Physics at the University.

• **Italy** Another protest that the Government is failing to provide enough money for nuclear research has been made by the staff at the Ispra Research Centre and the Association of Physicists-Research Workers.

• **Japan** The Japan Atomic Energy Research Institute is negotiating a contract with the French CEA Institute at Saclay to obtain help in building an isotope producing plant planned near the Tokai-Mura centre.

• **Russia** A 10 MW pool-type reactor went critical recently at the Soviet Academy of Science's Physics and Technology Institute.

• **United States** A new 100 kW reactor is being designed by Aerojet-General Nucleonics for the Army's Aberdeen Proving Ground; it will be known as Opera—Ordnance Pulsed Experimental Research Assembly—and will produce pulses of radiation.

Ship safety panel reports

Nuclear merchant ships can be built and operated within acceptable standards of safety. This was the main conclusion of the Parliamentary Committee that was appointed in March 1958 'to advise the Minister of Transport and Civil Aviation on the safety problems arising from nuclear propulsion in merchant ships at sea and in port.' In its report (Cmnd. 958), presented to Parliament recently, the committee laid down a number of design and construction rules for surface ships.

The completion of the British report on safety coincided with this meeting organised by the International Atomic Energy Agency in the Hofburg, Vienna, to discuss the question of liability for nuclear ship accidents. 23 countries, including the UK, were represented

In general, the recommendations differ very little from the principles laid down for land-based projects; they cover the design of the reactor and containment from the point of view of shielding, efficient cooling, instrumentation, radiation detectors and monitoring systems. Emphasis is made, however, on the question of containment; all primary circuit parts are to be totally enclosed, with the containment structure and shutdown assemblies shock resistant, to protect them against collapse arising from external sea water pressure. In the design of the structure account is to be taken of the possible need to salvage the reactor installation from a sunken ship. Use of explosives in these circumstances would be prohibitive and very heavy lifts would be required to raise the weight of the reactor installation. The Admiralty would be the most likely authority to be called upon for this task because they were the only people possessing the right type of equipment.

With reference to the ship's attitude, whilst a list of 20° is to be considered normal, the coolant system has to function safely under all foreseeable operational and accident conditions at all angles of heel and list up to 70°. Furthermore, reactor shut-down arrangements are to be designed for efficient functioning up to an angle of 90°, unimpaired by structural distortion of pressure vessel or core. They are to operate even when the ship is submerged.

For navigational purposes, the long-term aim is to allow nuclear ships to operate under no greater restriction than conventional ships. Nevertheless, conditions have to be made for safe operation in shipping lanes and crowded waters. Because of the restrictions of power (flexibility imposed by the maximum rate of reactor power charge), and the probability of complete power failure, auxiliary power must be available for propulsion at a navigable speed for a period of not less than five days without nuclear power. This rule applies particularly to a one-reactor system; with a system of two or more reactors, power to the turbines is to be divided equally to allow at least one reactor to operate safely.

International control

The Safety Committee's report represents the first comprehensive study made of such problems in any country, and it was particularly fortuitous that it appeared in time for the meeting of the Nuclear Ship Panel of the International Atomic Energy Agency, a few weeks ago.

Aspects of radiation hazards have already received the attention of other bodies; Article 25 of the International Convention on the High Seas, 1958 emphasized the measures to be taken by governments to prevent pollution of the seas by dumping of radioactive waste. The International Commission for Radiological Protection, it will be remembered, had previously made recommendations on maximum permissible concentrations of radioisotopes in air and water.

Then in September 1959 the International Maritime Committee, IMC, representing 24 national associations of maritime law, made a draft convention on liability in the operation of nuclear ships, but a number of questions were left open and it was the task of the IAEA panel to reach conclusions that could be submitted to the governments concerned. The question of settling questions of liability was all important because the absence of international rules might well lead to insufficient compensation to the victims, claims that could not be financially covered by persons involved in the construction, operation or repair of nuclear ships.

The overall problem of nuclear ship operation is therefore receiving urgent attention at top level in all maritime countries and the UK recommendations should make a valuable contribution in the formulation of international regulations.

Francis Perrin, High Commissioner of the Commissariat à l'Energie Atomique, writes this special preface for NUCLEAR POWER'S issue on

ATOMIC ENERGY IN FRANCE

THE DISCOVERY made by Otto Hahn at the beginning of 1939 of the fission of uranium atoms by neutrons made it possible—especially after the work of Frédéric Joliot—to think out the concepts of atomic reactors and visualize the vast industrial development which could result from their realization. The team led by Joliot was one of the most advanced along this path when it was compelled to give up its work by the invasion of France in June 1940. A few French physicists and chemists nevertheless were able, during the remainder of the war, to make their contribution to the work of our Anglo-American allies, mainly within an Anglo-Franco-Canadian team working in Canada (in Montreal, then at Chalk River).

After the liberation of France and the spectacular success of the immense American effort culminating in the creation of atomic weapons, France's Provisional Government led by General de Gaulle, decided to create an Atomic Energy Commissariat despite the backlog and the weakness of French scientific research and French industry due to the German occupation, and in creating it to organize a great national effort to resume research on nuclear energy while preparing the country to use it industrially and, possibly, for the defence of the nation.

In the first stage, the Atomic Energy Commissariat (CEA), under the leadership of the High Commissioner Frédéric Joliot and the General Administrator Raoul Dautry gathered together the basic equipment and personnel needed to carry out its task. Around the handful of specialists who had been members of the pre-war team, or who had returned from Canada, a rapidly increasing number of scientists and engineers—including many new graduates—were initiated into the new techniques required to design and build nuclear reactors. A first atomic pile, natural uranium/heavy water, went critical at the end of 1948 at the first French nuclear research centre situated in an ancient disused fortress at Fontenay-aux-Roses. Intense prospecting campaigns resulted in the discovery and the opening up of important uranium mines in metropolitan France. A new atomic research centre, with a high capacity for expansion, was built at Saclay, some 20 km south of Paris. From the start, high powered equipment was provided including a second natural uranium/heavy water reactor developing 2000 kilowatts (heat) and cooled by carbon dioxide circulating under pressure.

In 1952, the results obtained enabled the establishment of a five-year plan aimed at placing France in a position to undertake industrial production of atomic energy by the natural uranium-plutonium route. This route, at the time uncharted, seemed promising and offered the hope of achieving—perhaps in the distant future—the complete burnup of uranium through plutonium breeding, without any need to make the heavy and technically difficult effort of building a plant to enrich uranium in its fissile isotope, uranium-235.

An essential section of the programme was the construction of a plutonium production centre, and this was set up at Marcoule in the Rhône Valley. The first converter, G1, was cooled by air at atmospheric pressure; in the second, G2, the heat was extracted by carbon dioxide under pressure and it proved possible to use the heat for a net output of 25,000 kilowatts. In 1955, it was decided to build a third reactor, G3, at Marcoule, identical with G2, and to increase the size of the plutonium production plant accordingly. All these facilities are now operating and Marcoule has an annual production capacity of more than 100 kilogrammes of plutonium and will be able to feed some 50,000 kilowatts of electricity into the grid of Electricité de France. The first of EDF's own stations, called EDF1, is to go into operation next year at Chinon in the Loire Valley.

In the meantime, the CEA has continued to expand and equip its Saclay and Fontenay-aux-Roses research centres, has set up a new centre at Grenoble closely linked with the University of that city and has just begun to build yet a fourth centre in a sparsely populated area of the Durance Valley at Cadarache. At this latter station a number of experimental reactors will be installed, in particular a fast reactor cooled by molten sodium, designed to burn plutonium and destined to prepare the way for the construction of a prototype breeder reactor.

While following the plutonium route in this way, France has decided to build a gaseous diffusion plant for isotopic separation of uranium, in order to be able to fuel nuclear power plants with enriched uranium and especially to ensure the supply of highly enriched fuel for the atomic propulsion units planned by the French Navy.

PLANS AND PROGRESS

This section of five articles giving a short survey of the French scene is opened by Marcel Flouret, Président du Conseil d'Administration of Electricité de France

ATOMIC ENERGY IN FRANCE

EDF's nuclear programme

WHETHER CONVENTIONAL or nuclear, all the construction problems of Electricité de France have one factor in common: the rapid growth of electric power consumption which follows the well-known statistical law of doubling every ten years. In 1959, national consumption reached 64·6 thousand million kWh. It is expected that the demand will be 100 thousand million kWh by 1965, and about 200 thousand million by 1975.

The obvious consequence of this geometric progression of consumption is that a day will inevitably come when conventional reserves of energy will be insufficient to face the increase of our needs. It will then be necessary to resort to nuclear energy whatever its cost, which in any case will fall as a result of technical progress.

The only question is to ascertain the time available to perfect this new technique which, at the moment, costs more than conventional power.

In this respect, the position of France has considerably improved in the last three or four years. Whereas our country had to import about 40% of the primary energy it required, with a tendency towards increase of this proportion, the discoveries of natural gas in the South-West of France and of petrol in the Sahara have reversed this trend. France, thanks to these new resources, and thanks also to her hydro-electric and coal resources, is now certain to have sufficient time to master the nuclear technique without undue haste, but this does not mean carelessly.

The nuclear programme of EDF is a compromise between the wish to produce energy at the lowest price and the need to carry out research and development on a sufficient scale to be ready at the time when the atomic power will have to take over. In other words, our programme does not seek to increase our energy resources, which are at the present time sufficient, but to acquire knowledge which will become indispensable in the future. Hence a programme of prototypes which avoids duplication until atomic energy is competitive, or almost so.

This programme is nonetheless very important, as in order to bring results our experiments should be made on an industrial scale and not merely in the laboratory, nuclear technique demands in effect full-scale projects because extrapolations are not practical.

A summary of the programme of Electricité de France is given in the table below.

What perspectives will open after its realization? If the competitive level is reached, we will build several stations of similar design. Otherwise, the prototype period will be prolonged until a competitive level is reached and in the worst case when the resources of conventional energy are exhausted.

Outline of France's nuclear electric power programme

	STATION	ELECTRIC POWER MW (NET)	TOTAL COST MILLION NF
1955	G2–G3	50	65
1956	EDF 1	60	162
1957	EDF 2	170	290
1959	EDF 3	over 300	510

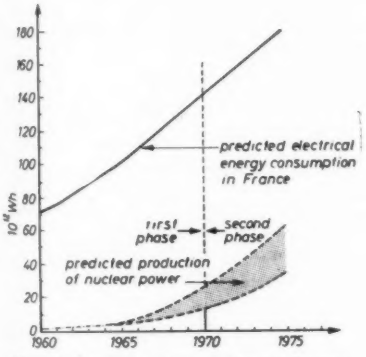
This view of EDF's Chinon site shows EDF1 (left centre) and EDF2 (right)

ATOMIC ENERGY IN FRANCE

Economics of Nuclear Power

J. ANDRIOT, *CEA*

TAKING into account the official electrical energy programme, and in particular that of nuclear origin, the evolution of nuclear power in France can be forecast as indicated in Fig. 1. In this diagram we give the forecasts for the consumption of electrical energy up to 1975; production of nuclear power under the official programme is indicated in broken lines, while the possible or probable long-term extension of nuclear power generation is shown shaded.



Electrical energy consumption in France is projected up to 1975 (Fig. 1)

The short term economic problems mainly concern prototypes. Numerous problems of costing small production runs are involved when fuel elements are manufactured, when they are chemically processed or when selections (or decisions) have to be made during the construction of a reactor. The importance of ancillary facilities (storage of fission products), the expediency of improving the quality of nuclear graphite, the size of production or processing plants, all these give rise to economic studies restricted in their subject but in which the distant objectives cannot be ignored.

For the successive prototype nuclear power stations of a series, a rate of construction should be defined in such a way that the maximum benefit can be reaped from technical and economic improvements. In particular, the construction of one station involves complementary expenditure linked with preceding and succeeding plants.

Figure 2 shows an extensive programme for two series of nuclear power stations and for thermal plants using imported coal, the budgeting for capital investment and running costs being calculated on a yearly basis. The programme is taken over a ten-year period (or 14 years after the start of construction). The Figure shows the different incidence of certain economic sectors (mines, heavy water) and the importance of harmonizing the rate of development with the best utilization of the investments made for the construction of the various components of the nuclear reactors (in the case of heavy water).

The difference between these various budgets, especially in the initial years, represents the investment effort which has to be made, an effort which will not bear its reward until much later. But it is the price which must be paid to set up a new industry and obtain practical experience.

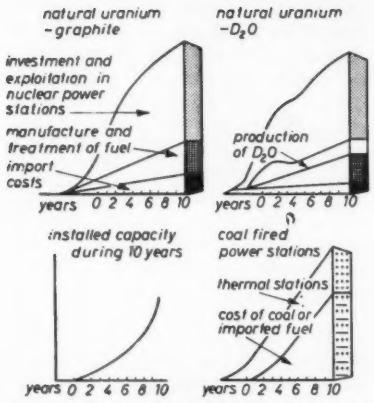
The short term programme is concerned with pilot installations on a large scale, and the extrapolation of figures resulting from these is obviously delicate.

In these short term studies we usually allow for:

- an interest rate of 6%
- a value for natural uranium of 180NF/kg, as crude metal
- two buy-back prices for civil plutonium: 60NF and zero NF/g
- a zero value for deplenished plutonium
- a lifetime for prototypes 10 years, for pilots 5–10 years
- a price for heavy water of 0·30NF/g
- a price for graphite of 6NF/kg

On a long term basis there will be established all over the world a market of materials, components and nuclear instruments related to all types of power station then in development. This market probably will result in an end to the appreciable reductions in cost of natural uranium (and as a result, of enriched uranium), heavy water, graphites, canning and chemical treatments.

On the other hand, the technical performance of the reactors will be improved (specific power, burnup etc.). These economic 'trends' can be used to present as many solutions as there


natural uranium -graphite
natural uranium -D_2O
investment and exploitation in nuclear power stations
manufacture and treatment of fuel
import costs
production of D_2O
years 0 2 4 6 8 10
installed capacity during 10 years
coal fired power stations
thermal stations
cost of coal or imported fuel

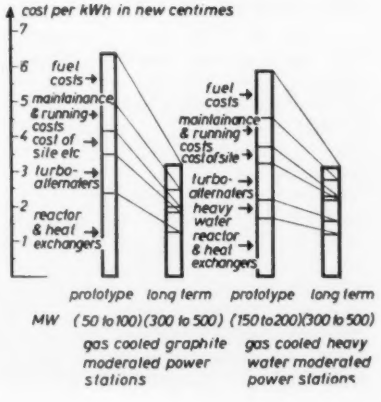
The cost of a two-system programme (Fig. 2)

are economists. But among many other possibilities equally valid, it can be accepted that the basic production cost per kilowatt-hour in our two main chains of power station series could be as follows (see Fig. 3):

- interest rate reduced to 5%
- value of natural uranium 100NF/kg
- buy-back price for plutonium resulting from the existence of a chain of breeder reactors 40 NF/g
- life of power stations, 30 years
- value of heavy water 0·25NF/g
- price of graphite: 5NF/kg

We have indicated the variations in the cost per kWh for stations operating 6500 hours per year, but the diversity of the main chains of stations and their particular economic structure may mean that certain nuclear power plants could be used to meet peak demand. Here, one of the major economic problems will be to arbitrate between the various forms of primary energy and, in particular, decide on the sector of the graph, power versus load factor, which can be given over to nuclear power in France or in Europe.

Individual component costs for two systems (Fig. 3)



ATOMIC ENERGY IN FRANCE

The legal position

J. WEINSTEIN, *OEEC*

ATOMIC LEGISLATION in France today, with one notable exception—licensing and insurance—is similar in pattern to British legislation. Although the French Commissariat à l'Energie Atomique (CEA) has a wide mandate under the Ordinance of October 18, 1945, by which it was set up by General de Gaulle's provisional post-war Government to carry out scientific and technical research for the utilization of atomic energy in science, industry, and national defence, its role is not dissimilar to that of the United Kingdom Atomic Energy Authority under the 1946 and 1954 Acts.

Although the CEA, like the UKAEA, has no legal monopoly over atomic energy yielding substances, it has a factual monopoly over all fertile and fissionable materials in France and in the Overseas Territories. It is responsible for and controls, in agreement with other Government Departments, the exploitation of uranium or thorium mines and deposits of other substances, such as beryllium. Although prospecting is not controlled, declarations of discoveries of deposits have to be made, and the CEA can oblige those who exploit sources to make available the minerals extracted. On the other hand, fair compensation is paid for such minerals and the CEA gives considerable help in developing the search for and exploitation of resources.

Radioisotopes

Import of a number of materials such as uranium, thorium, lithium, bismuth, heavy water, as well as nuclear installations and equipment of all kinds, is subject to special authorization; export of these items is similarly controlled.

In the rapidly expanding use of radioisotopes in medicine, research, and in industry, a number of legislative measures provide that radioisotopes cannot be prepared, imported or exported other than by the CEA, except by special authorization, given by the Minister for National Education, when the isotopes come from or are destined for installations which are under his authority. In other cases, authorization is given by the Prime Minister, after consultation with a special Inter-Ministerial Committee set up under the Public Health Acts.

From January 1960 onwards, under a Government Decree similar in general scope to the Radioactive Substances Act, 1948, the sale, production and use of radioisotopes is subject to conditions laid down in Government regulations. No such regulations have so far been issued.

Nuclear installations

Electricity production in France is a monopoly of EDF, the nationalized electricity industry, and private undertakings may only produce electricity for their own needs. However, to enable private enterprise to play its part in the Euratom–US programme, a Decree of November 28, 1958, authorized the setting up of private French companies for the production of electricity of nuclear origin. The operation of any installation built is, however, reserved to EDF, which must hold at least half of the share capital in such companies.

For nuclear installations other than reactors for electricity production, an important Decree of April 15, 1958, laid down that privately-owned plants using radioactive substances cannot be put into operation without Government permission. Such plants were made subject to regulations laid down in a 40-year old Act governing 'dangerous, unhealthy and inconvenient establishments.' Authorization is also required for processing or treating radioactive substances and for their use or storage. Thus, while there is no equivalent to the formal licensing system introduced into the UK by the Nuclear Installations (Licensing and Insurance) Act, 1959, any undertaking dealing with radioactive substances is effectively subject to prior Governmental authorization and control. It will nonetheless be necessary to envisage new legislation, similar to the 1954 UK Act, for the future.

In the light of the directives on radiation protection norms issued by the Euratom Commission, and the substantially identical norms adopted by the OEEC, the French authorities are currently engaged in reviewing their health and safety rules and controls.

Whilst an Act of 1934 laying down the precautions to be taken when using and handling radioactive substances is still in force, in 1957 the French Ministry of Public Health issued new Recommendations on protection against ionizing radiations, which have the same scope and purpose as the UK's 1957 Code of Practice.

At the present time, although there are no projects of the same scope as the new UK Radioactive Substances Bill, an independent body under the National Institute of Hygiene is responsible for regulations relating to the storage and disposal of radioactive waste, including waste from CEA installations.

An Inter-Ministerial Commission, in which representatives of the CEA participate, has general responsibility for the application and revision of regulations for the transport of dangerous materials. The regulations governing the transport by railroad and inland waterways of 'dangerous and noisome substances' of 1945 were amended in 1956 to include radioactive materials. Similarly, the regulations governing the transport of dangerous goods by air and by sea were amended, in 1957 and 1958 respectively, to cover radioactive substances.

The French authorities have been considering for some time the need to establish a special regime for third party liability and insurance against atomic risks. No special legislation exists on third party nuclear liability and under the present law liability for nuclear incidents would be based on the Civil Code. In the view of leading legal specialists, Article 1384, which establishes absolute liability, would be applied by the Courts. In such a case, there would be no limitation of the amount for which a person might be liable and the period for bringing actions would be 30 years from the time when the injured person had knowledge of his injury and who was liable. Although the CEA and EDF are classed as 'public establishments,' the law to be applied at the present time in the event of a nuclear incident at their installations would be the same. The French Government, during the negotiations of the OEEC Third Party Liability Convention, made it clear that it envisages a system, similar to that in the USA and in Germany. Over and above what can

be obtained by way of insurance, State funds would be available for compensation of nuclear victims.

From this short survey it will be seen that there is little in the way of comprehensive atomic legislation in France; hitherto the process has been to adopt existing legislation to meet the problems of atomic energy as they emerge.

ATOMIC ENERGY IN FRANCE

How industry is organized

A. MOUTURAT, *Secretary-General ACEN*

INDUSTRY'S effort was initially directed to the production of essential materials: prospecting, exploitation of minerals, production of fissionable materials and manufacture of fuel elements. The Commissariat had shown the way, particularly in the treatment of minerals; it had even taken part in the formation of companies where it played an active part, like a private industrial concern. The result was to increase the participation of industry still further, and we recently saw a private company created to construct and exploit the Malvési works near Narbonne. Similarly in the construction of works for the production of uranium and thorium, the Commissariat has in the main called on specialized chemical companies.

Collaboration with CEA

However it could be said that industry's effort really developed from 1952, when the first five year plan was put in action, and especially with the erection of the Centre at Marcoule. This was the occasion for industry to start acting as contractors in the successive construction of the three reactors G1, G2 and G3 and to produce new techniques as well as inventing brand new materials to meet new needs. Good examples were the original work required to make pressure vessels in prestressed concrete, and the mechanical ingenuity of the equipment for on load charging and discharging of G2, while the contribution of the chemists for the plutonium separation plant should not be forgotten. Fuel element research has been extensive and one company is today producing for national and export requirements pastilles of fused uranium oxide. Interest in enriched uranium-fuelled reactors has grown and private industry is collaborating with the CEA in building the diffusion plant. Reactor grade graphite is now available for export, and heavy water is in production. There have been echoes in the press recently of the success of the installation erected at Toulouse by French industry in association with the Commissariat and the National Office of Nitrogenized Industries (l'Office National Industriel de l'Azote).

Industry has also played a large part in the expansion of CEA facilities, notably in the construction of research reactors such as EL2, EL3, Alizé, Aquilon and Proserpine, as well as the pool reactors Mélusine, Triton and Minerve.

The formation of special groups covering civil, mechanical, and electrical engineering, and electronics, started after the construction of G1 with the first nuclear company, France-Atome, after working together at Marcoule. Other companies formed Indatom, another specialized group. These two have been followed by other concerns which have in their turn formed nuclear companies, under the auspices of joint stock companies or limited liability companies. The principal groups are now Auxi-Atome, Caratom, CERCA, CFMU, Dynatom, Framatome, GAAA, SATNUC, SCUMRA, SODERN, and SRTI.

Four years ago the Technical Association for the production and utilization of Nuclear Energy—ATEN—was formed under the patronage of the Commissariat à l'Energie Atomique and Electricité de France. An independent organization, it seeks to make known every aspect of nuclear energy from the points of view of both production and use; it is non-profit making, and links the majority of the French companies participating, or eager to participate, in nuclear activities. In collaboration with similar societies, ATEN arranges congresses, conferences, and meetings, takes part in exhibitions in France and abroad, and runs an information service on technical reports upon which its members can draw. But the actions of the ATEN are not limited to a single national plan. The association keeps in touch with corresponding bodies in the Euratom countries; and a new organization has just been started with a provisional committee including representatives from the associations similar to ATEN in all six countries.

On another plan the GIIN (Groupement Intersyndical de l'Industrie Nucléaire) was formed in 1959. It represents the professional organization specializing in nuclear energy. Within the framework of the Euratom countries a Union of Industries of the European Community (UNICE) groups the professional concerns interested in nuclear activities. Another organization in France which should be mentioned is the Brevatome Association, whose object is to disseminate useful patent information to its members. In exchange the members entrust it with the management of their proprietary requests in industrial matters.

Associations abroad

In the spirit of cooperation exemplified in the creation of Euratom it was natural that French enterprise should seek collaboration with foreign companies in building nuclear power stations as was in the case at Chooz in the Ardennes. Involved in the construction of this project are different companies: Dynatom (associated with Atomics International for the organic moderated reactor), Framatome (with Westinghouse for the pressurized water type), Indatome (with Babcock & Wilcox, also for the PWR) and Alsthom who are associated with General Electric for the boiling water reactor.

An interesting point should be noted here. It is laid down that in the choice of an approved undertaking, the im-

CEA's industrial centre at Marcoule. Left to right are G2, G3, plutonium extraction plant and G1

portance of work directly realizable by European companies should be taken into account. It must be said that several companies, in submitting their plans, did not wait for Euratom to approve their proposals before joining with American associates.

Besides Euratom, OEEC has called on industry for work on the Eurochemic project and a French chemical company has been named to play an important part in the construction and operation of the proposed installation at Mol, in Belgium. Other foreign work undertaken includes several projects in Germany, notably one at Karlsruhe, for the building of hot laboratories.

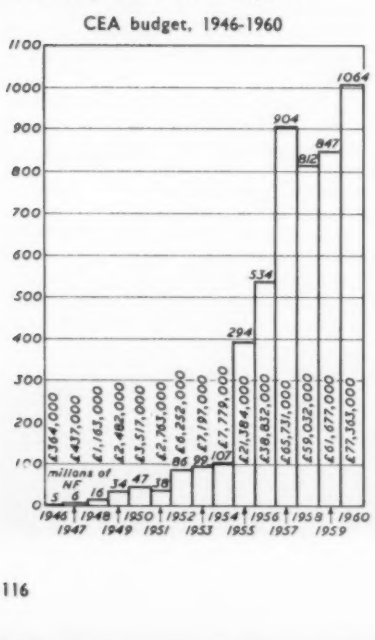
ATOMIC ENERGY IN FRANCE

The CEA and its work

J. BURKETT, '*Nuclear Power*'

EXPENDITURE which started at about £364,000 in 1946 increased rapidly and for 1959 it was nearly £M62 representing an expenditure per head of population of about 30 shillings as compared with 42 shillings for the United Kingdom. The amount budgeted for 1960 now exceeds £M77. Since 1956 the Commissariat a l'Energie Atomique has received loans from the Economic and Development Fund, FDES, for financing the industrial programme; these have grown from one-tenth of the total expenditure in 1956 to nearly one-quarter of that for 1960. These loans are intended for the production of uranium ore, transformation into metallic uranium and the manufacture of fuel elements for the EDF nuclear power stations, in addition to reactor research, particularly for a natural uranium, heavy water type, construction of which is planned for this year.

CEA budget, 1946-1960



The second five-year plan which was launched in 1957 changed in emphasis from the first plan by ceasing to be responsible for all atomic energy in France. Other government agencies and public corporations, led by Electricité de France, together with many of the leading industrial firms, are now playing a substantial part. In the field of fundamental research, CEA, with increased resources, has continued investigations in nuclear fusion and in collaboration with EDF, temperatures of the order of one million degrees Centigrade have already been achieved in the 'Equator' apparatus.

Progress is being made in the biological field, not only on efforts to learn more about radiation protection methods but also in the exploitation of radioisotopes. New materials that are being developed for industrial manufacture include beryllium, zirconium and heavy water. Plutonium passed from the pilot plant stage to full industrial production when the plutonium factory was constructed at Marcoule.

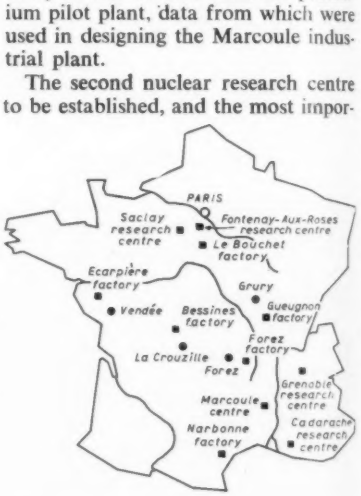
New equipment for furthering the aims of the second five-year plan includes the low power experimental reactors Triton, Minerve and Alizé, and Rapsodie, a fast neutron reactor. EL3 is to be supplemented by EL4 for testing materials and high temperature experiments are to be carried out, particularly for research into the possibilities of gas turbine applications.

In conjunction with the EDF programme of power station reactors, work is being done on fuel configurations, heat transfer and Wigner effect in graphite. Close collaboration with EDF does not necessarily tie CEA to that particular generation of reactors and it is intended to develop power prototypes for experiments on liquid metal and beryllia systems, in addition to a fast neutron reactor. With its 1957–61 programme well under way, France is seriously entering the industrial phase of nuclear development.

The Research Centres

The first French nuclear centre established in 1946 grew up in temporary accommodation in the former fort at Châtillon, and by 1950 more than 800 persons were at work. After Saclay was completed, the old centre was rebuilt and given the name of Fontenay-aux-Roses. Reactors other than EL1 are Triton for radiation protection studies and Minerve for studying the degree of purity of nuclear materials. Apart from providing new knowledge on the nature and structure of uranium and thorium ores, Fontenay's research staff built the plutonium pilot plant, data from which were used in designing the Marcoule industrial plant.

The second nuclear research centre to be established, and the most important, was Saclay in 1945, employing over 3000 people out of a total of some 14,000 for the whole of the CEA. Among the special apparatus installed are two electrostatic Van de Graaff type generators, one 2 MeV and another 5 MeV, a 25 MeV cyclotron and a 28 MeV linear electron accelerator. The largest accelerator, the 3 GeV Saturne synchrotron for proton charging, went into service in August 1958. In the reactor field, the centre is equipped with five experimental reactors: EL2, the first pile to be cooled by forced gas circulation; EL3, a high neutron flux pile for testing materials; Aquilon, designed for the study of natural uranium-heavy water systems; Proserpine, a homogeneous reactor for criticality experiments; a reactor for the study of uranium-beryllia systems; and Alizé for the analysis of the properties of enriched uranium-light water systems.



■ scientific and industrial establishments
● mining divisions

Among the important departments carrying out research at Saclay is one for physical chemistry charged with the study of industrial isotope separation; another for uranium isotope separation, where experiments have led to the design for a full-scale separation plant in the south of France; and the radioisotopes division responsible for user production.

The third nuclear research centre, Grenoble, was established in the provinces and, although its aims are analogous to Fontenay and Saclay, the essential difference is its close liaison with the neighbouring university, without which it would have been impossible to start. Another feature was the close collaboration with regional industry (e.g. Péchiney, Ugine, Neyrpie and Melin-Gérin) and the encouragement given for maximum participation in the atomic field. Its activities, which started early in 1958, include pure physical research, solid state chemistry and radiation chemistry. Facilities include a 1·4 MeV ion accelerator, a 600 keV electron accelerator, and a 1·2 MW swimming pool reactor Mélusine offering greater flexibility for experiments.

FRENCH REACTORS

Name	Location	Date Critical	Max. thermal flux	Max. thermal power	Fuel	Moderator	Coolant	Elec. output	Purpose
EL 1 (Zoé)	Fontenay-aux-Roses	15-12-1948	10^{12}	150 kW	U nat.	D_2O	D_2O	—	research
EL 2	Saclay	21-10-1952	10^{13}	3 MW	U nat.	D_2O	CO_2	—	,,
EL 3	Saclay	4-7-1957	10^{14}	15 MW	U enr. 1·4%	D_2O	D_2O	—	research and material testing
Aquilon	Saclay	11-8-1956	10^{7}	0	U nat.	D_2O	nil	—	lattice studies
G 1	Marcoule	7-1-1956	5×10^{12}	40 MW	U nat. 100 t	graphite 1200 t	Air (atmos.)	5 MW	Pu production and electricity
G 2	Marcoule	21-6-1958	$2{\cdot}5 \times 10^{13}$	200 MW	U nat. 150 t	graphite 1200 t	CO_2	28 MW	,,
G 3	Marcoule	11-6-1959	$2{\cdot}5 \times 10^{13}$	200 MW	U nat. 105 t	graphite 1200 t	CO_2	28 MW	,,
Proserpine	Saclay	17-3-1958	5×10^{7}	nil	Pu sulphate (homog.)	H_2O	nil	—	criticality studies with Pu
Mélusine	Grenoble	1-7-1958	10^{13}	1·2 MW	U enr. 20%	H_2O (pool)	H_2O	—	research
Triton	Fontenay-aux-Roses	July 1959	10^{13}	1·2 MW	U enr. 20%	H_2O (pool)	H_2O	—	protection studies
Alizé	Saclay	June 1959	5×10^{7}	weak	U enr.	H_2O	nil	—	lattice studies
Minerve	Fontenay-aux-Roses	Sept. 1959	10^{11}	weak	U enr. 20%	H_2O (pool)	H_2O	—	purity of materials analysis
EDF 1	Chinon	1960	$4{\cdot}5 \times 10^{13}$	300 MW	U nat. 150 t	graphite	CO_2	60 MW	electricity production
EDF 2	Chinon	1961	—	700 MW	U nat. 250 t	graphite	CO_2	170 MW	,,
Rapsodie	Cadarache	1963	10^{15}	10 MW	Pu	—	Na	—	experimental
Pégase	Cadarache	building	—	20-30 MW	U enr. 20%	H_2O (pool)	H_2O	—	research
Brenda	Cadarache	building	—	—	U enr.	—	gas	—	research
EL 4	Marcoule	comm. building 1960	—	100 MW	U nat.	D_2O	CO_2	—	research

The Saclay nuclear research centre operates five reactors including Proserpine, Alize and Aquilon. EL2 and EL3 can be seen at top of photo

The necessity for a further research establishment has now become apparent and work has recently been started at Cadarache for the construction of a fourth nuclear centre, the cost of which will be some NFM20. As with Grenoble, it is sited near to a university, that of Marseilles, and in an area of highly organized industry. The aim is to make this centre in the Durance Valley as significant as Oakridge in the Tennessee Valley. At Cadarache, CEA will use three experimental reactors for research on design and performance improvements of existing French reactors. Pégase, a swimming pool type, will be used for experiments on fuel elements used in the gas-cooled reactors of EDF; Brenda, will be a high temperature reactor for feasibility studies on the use of gas turbines; and Rapsodie, a fast neutron system cooled by liquid sodium, will serve for experiments on breeder systems.

Also in the Marseilles area is the Plutonium Production Group at Marcoule where the three large reactors, G1, G2 and G3, are being operated. The first section of the group to start operating, in 1954, was the graphite machine shop which not only supplied the graphite required for the Marcoule reactors but also for all the other French reactors. The plutonium extraction plant which commenced operation in 1958 has an estimated output of some 220 lb of plutonium annually.

France has largely wiped out her arrears in relation to other great nations, according to M. Soustelle, Minister for Atomic Affairs, and, since atomic power is not yet competitive, and because of Sahara oil, France's programme is now aimed at perfecting techniques and proving her nuclear power industry for the future.

A typical open soil uranium mine; estimated resources in France are 50–100,000 tons. Exploitation is the job of four mining groups under the Directorate of Prospecting and Mining, DREM; 1961-2 target for pure metal is 1500 tons

The heads of the Electricité d
France divisions join to describe E DF2

THE SECOND NUCLEAR POWER STATION

M. BIENVENU, *Head of Design Department*

M. Boris SAITCEVSKY, *Head of the Reactor Division*

M. François BOURDILLAT, *Head of the Electricity Division*

M. Claude TOURGERON, *Head of the Mechanical Engineering Division*

M. Roger MILLOT, *Head of the Civil Engineering Division*

M. LAMIRAL, *Head of Planning and Organization Department*

M. Louis LAURENT, *Engineer in the Reactor Division*

ATOMIC ENERGY
IN FRANCE

THE EXPERIENCE obtained by the Commissariat à l'Energie Atomique with the G2 and G3 reactors as Marcoule and by Electricité de France with EDF 1 at Chinon has brought out the merits of this type of reactor and the advantages of large unit capacities.

At the outset, when it was decided to construct EDF 2, it seemed possible that the reactor could contain, without major risk, about 240 tons of uranium. The first calculations showed that such a reactor would give 150-180 MWe gross.

Experience has shown that the capacity of the reactors can be increased either during design or construction or even in the course of their life. It was therefore decided to install two sets of 115/125 MW capacity. This size is at the present time a standard for EDF conventional power stations. Heat transfer experimental investigations have made it possible to increase the net electric power output up to 170 MW and possibly even to 200 MW.

Furthermore, the original design temperatures were too low to keep Wigner effects to acceptable limits.

The design margins permitted an increase of the CO_2 inlet temperature from 170° to 200°C, but it was unfortunately too late to modify the turbines, because the steam pressures could not be altered to suit. This meant that there was no real increase in output.

All design efforts were directed towards making EDF 2 as compact as possible. We are convinced that it is only at the general design stage that the most economic layout can be achieved and that in this respect the detailed plant design is relatively less important. A cross-section through the reactor is shown in Fig. 1.

A thorough initial layout study is the only way to ensure that each item of equipment will be designed in the easiest and best possible way.

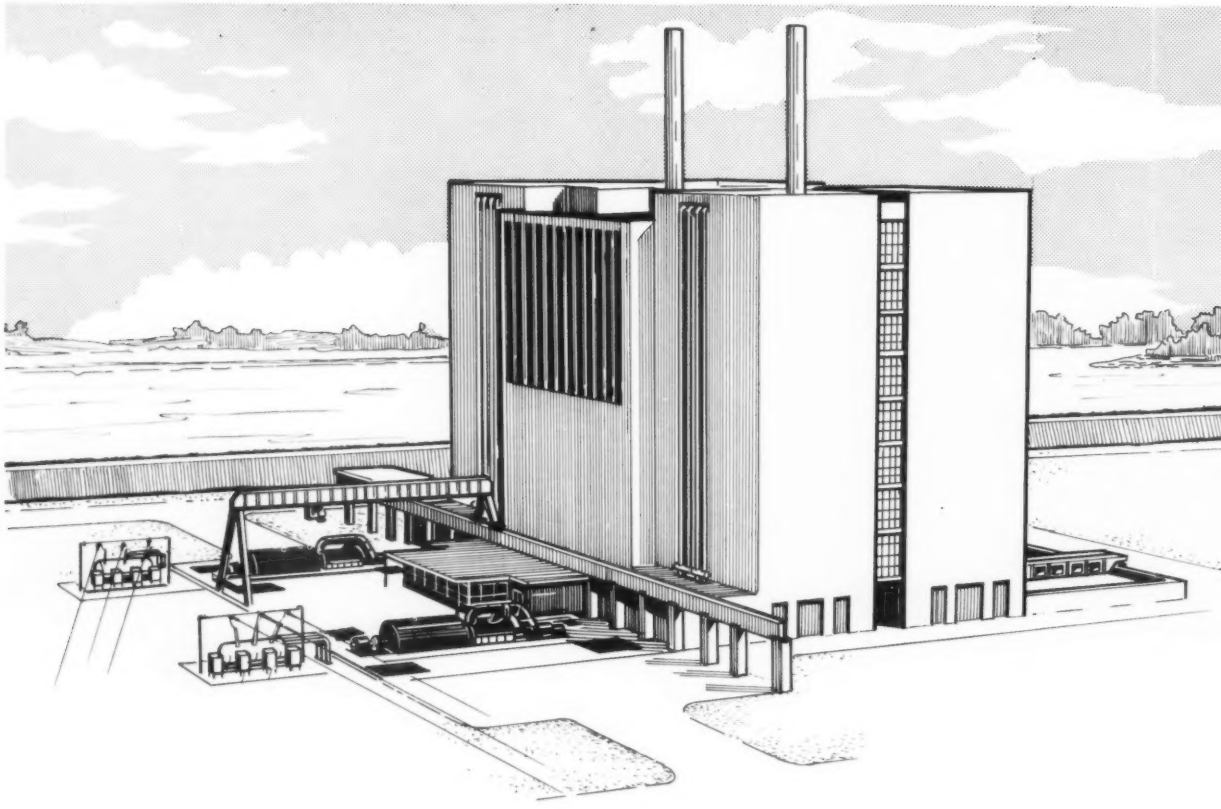
The operation of G2 and G3 has shown that, except during charging/discharging, a reactor is flexible and easy to handle. We have concluded from this that it would be easier to completely automate a nuclear power station than a conventional one for which the combustion of fuel still presents many problems. It is this conception of complete automation which has been at the basis of the design.

EDF 2 represents an important step towards the easy and economic operation of nuclear power stations within a large system. We are, nevertheless, convinced that there still remains much to be done in simplifying the different parts of the plant and particularly the reactor instrumentation, the fuel handling equipment, and the steam and CO_2 circuits. This is the basis of the design of the next reactor, EDF 3.

MAIN STATION DATA

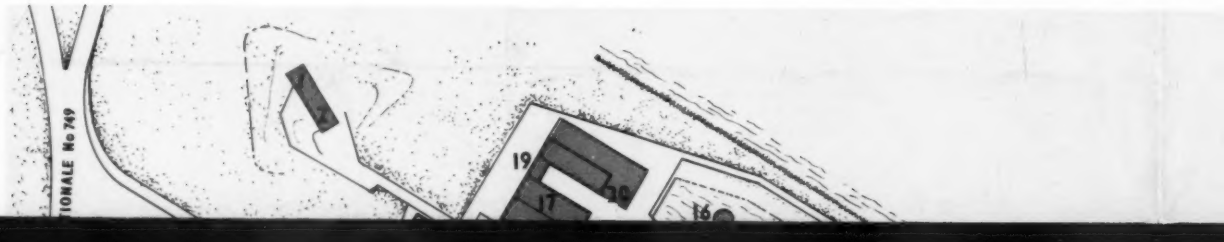
Reactor	
Thermal power	791 MW
Net electrical power	198 MW
Fuel natural uranium canned in Mg alloy	
Graphite	2200 metric tons
Core length without reflector	23 ft 7 in.
Core diameter without side reflector	40 ft
Neutron flux at core centre	3×10^{13} n/cm² s
Cooling circuit	
Maximum pressure of CO_2	368·4 lb/in²
Total mass of CO_2	100 metric tons
Inlet temperature	195°C
Outlet temperature	365°C
Gas flow (700 MW)	8488 lb/s
Heat exchangers	
Number	4
Number of elements per exchanger	24
Height of element	984 in.
Diameter of element	38·6 in.
Steam conditions at exchanger outlet	
H.P. steam:	
Pressure	472·8 lb/in²
Output	$4 \times 105{\cdot}8$ lb/s
Temperature	340°C
L.P. steam:	
Pressure	126 lb/in²
Output	$4 \times 57{\cdot}3$ lb/s
Temperature	340°C
The H.P. and L.P. circuits are independent	
Turbine	
Steam conditions H.P.–L.P.	
Pressure	458–122 lb/in²
Output	211·6–114·6 lb/s
Temperature	339°C
2 admission pressures	
4 exhausts	
2 bleed points	
Blowers	
Power (4)	6000 kW

CENTRALE NU



1 Welfare amenities
2 Canteen
3 Cloakrooms
4 Showers
5 Check point
6 Parking areas
7 Management offices
8 Technical departments
9 EDF1
10 High voltage switchyard
11 Cooling pond
12 Turboalternator
13 EDF2
14 Intake channel
15 Pumping station
16 Water tower
17 Stores
18 Workshop and garage
19 Water filter
20 Uranium storage

1 Services sociaux
2 Restaurant
3 Vestiaires
4 Douches
5 Pointage
6 Parking
7 Direction
8 Services techniques
9 EDF 1
10 Poste d'evacuation d'energie
11 Piscine de désactivation
12 Groupe turbo alternateur
13 EDF 2
14 Canal d'amenée
15 Station de pompage
16 Chateau d'eau
17 Magasin
18 Atelier et garage
19 Filtrage des eaux
20 Stockage uranium

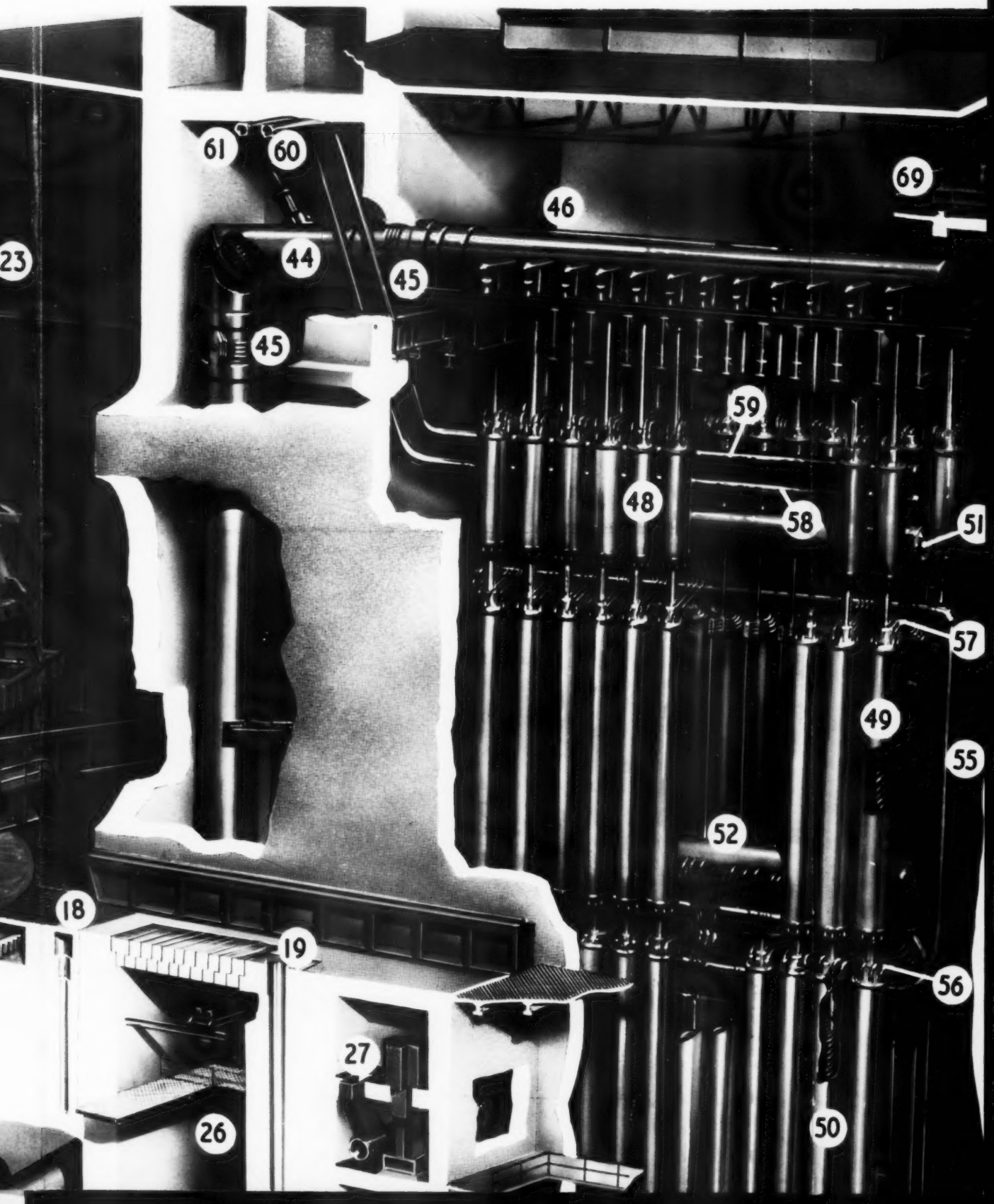


NUCLEAIRE ED

gie

EDF2 NUCL

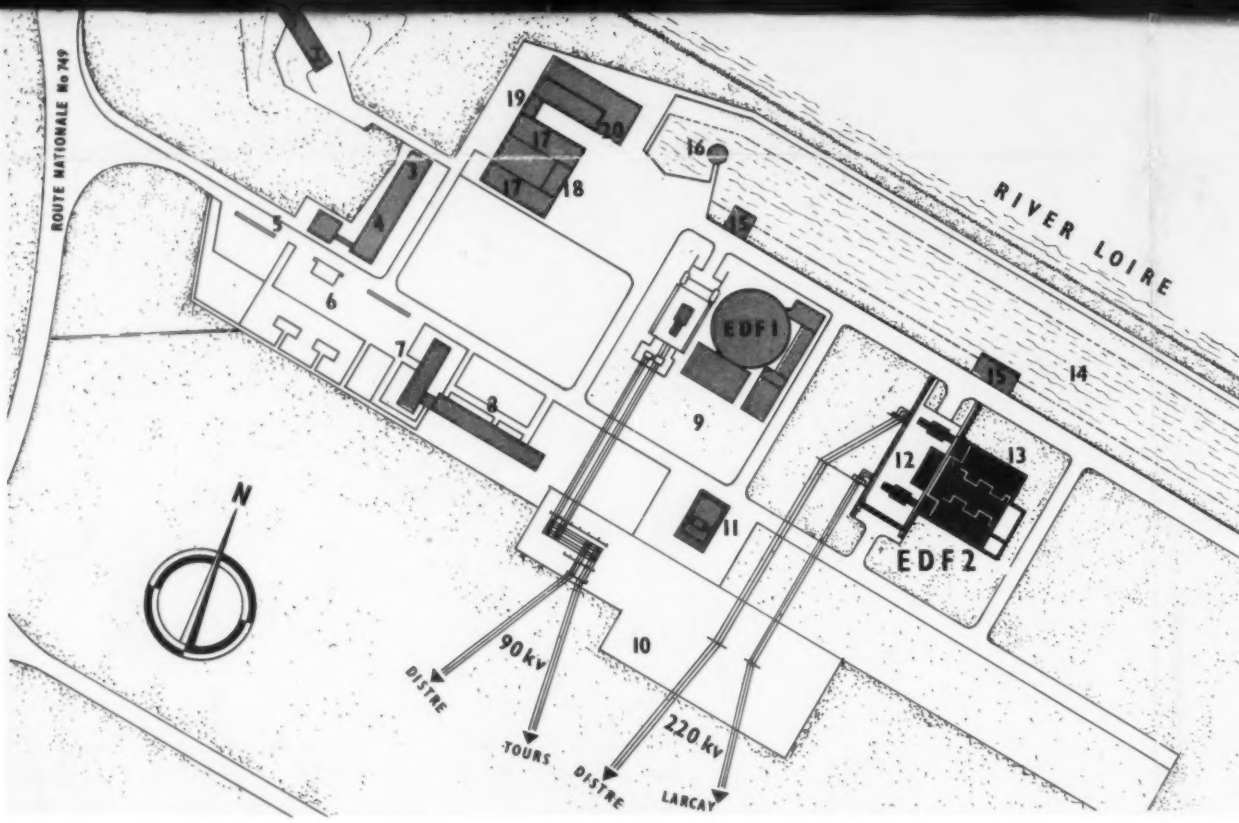
CLEAR POWER STATI



TATION

Légende

1 Caisson sphérique sous pression
2 Séparation du gaz chaud du gaz froid
3 Aire support de l'empilement
4 Empilement de graphite
5 Eléments combustibles
6 Pilier support du caisson
7 Plaque de lestage
8 Réflecteur en graphite
9 Pièce de réglage du débit de CO_2
10 Cuve de récupération des débris
11 Tuyauterie de récupération des débris
12 Puits de chargement
13 Tube pour barre de contrôle
14 Barre de contrôle
15 Local des treuils de barres de contrôle
16 Dalle de protection biologique
17 Dalle secondaire de protection
18 Puits de stockage pour treuil de barre de contrôle
19 Puits de décontamination des bras de chargement
20 Pont tournant
21 Machine de préparation de manutention
22 Machine principale de chargement déchargement
23 Pont transbordeur (charge 15 T)
24 Salle de commande et contrôle du chargement
25 Salle de relayage du chargement
26 Salle de décontamination des appareils de chargement
27 Ventilation de la salle de décontamination
28 Réservoir d'alimentation en CO_2 filtré
29 Salle de préparation des solutions de décontamination
30 Dispositif de sortie des tubes de détection de rupture de gaine (d.r.g.)
31 Réfrigérant primaire de d.r.g.
32 Sélecteurs de d.r.g.
33 Réfrigérant secondaire de d.r.g.
34 Filtre de d.r.g.
35 Prospecteur de d.r.g.
36 Armoire électrotechnique de d.r.g.
37 Surpresseurs de d.r.g.
38 Tuyauterie d'entrée du CO_2 dans le réacteur
39 Tuyauterie de sortie du CO_2 du réacteur
40 Mur de protection biologique de la soufflante
41 Moteur électrique d'entraînement de la soufflante
42 Soufflantes (4 semblables)
43 Coupleur hydraulique
44 Obturateur
45 Soufflet de dilatation



SITE: CHINON, FRANCE

OWNER: ELECTRICITE DE FRANCE

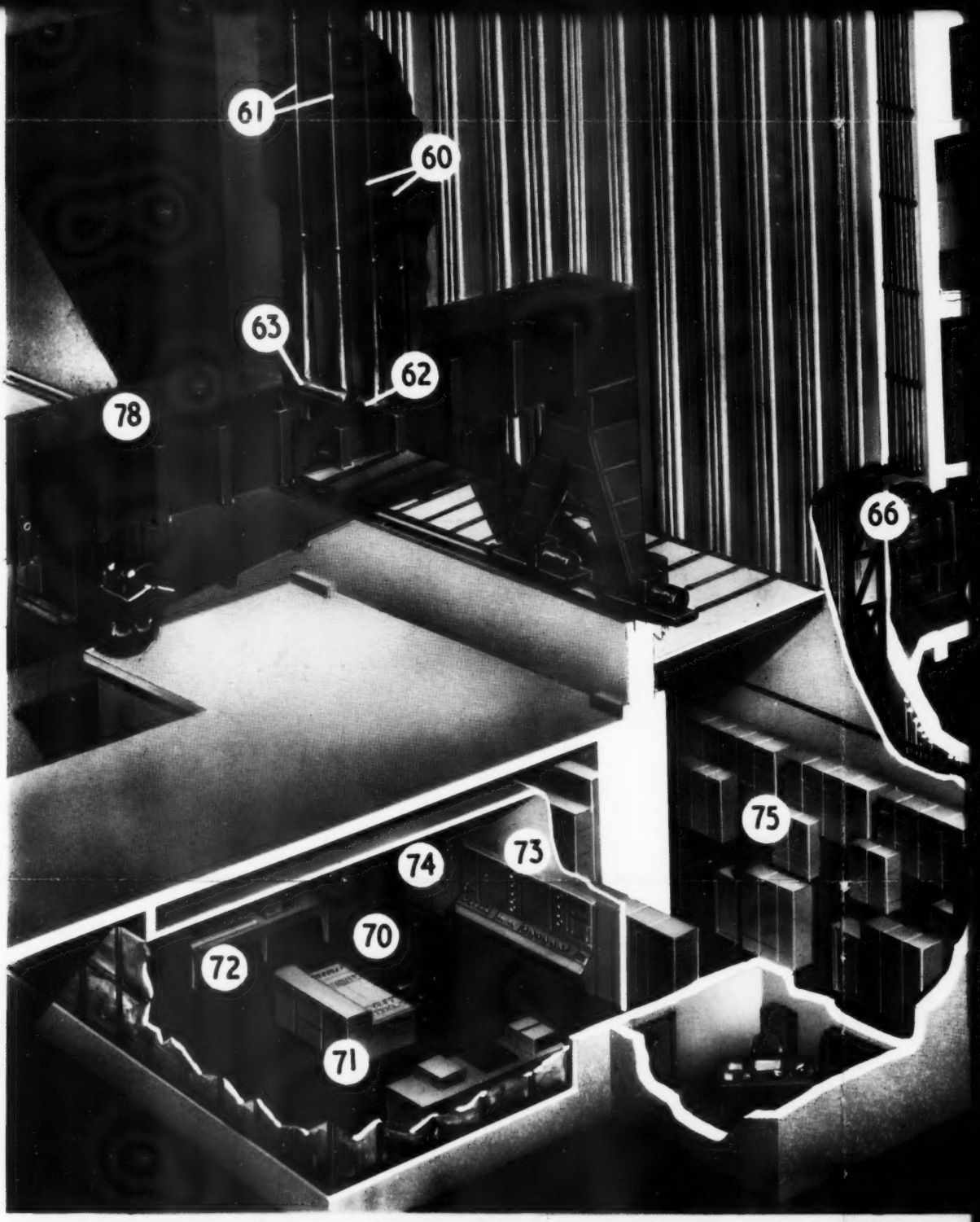
Main Allocation of Work

GRANDS TRAVAUX DE MARSEILLE (G.T.M.)	Civil Engineering
CIE DE PRODUITS CHIMIQUES ET ELECTRO-METALLURGIQUES PECHINEY	Graphite
STE INDUSTRIELLE DE COMBUSTIBLE NUCLEAIRE (S.I.C.N.)	Fuel elements
STE ANONYME DES ETS LEVIVIER	Pressure vessel
BABCOCK & WILCOX CIE DES ECHANGEURS CHANTIERS DE L'ATLANTIQUE FIVES-LILLE	Heat exchangers
STE INDATOM	Refuelling machine
ATELIERS ET CONSTRUCTIONS ELECTRIQUES DE DELLE	Winches and control rods
COMSIP-COCEI	Burst slug detection (b.s.d.)
CIE ELECTRO-MECANIQUE	Blowers and transformers
STE DES FORGES ET ATELIERS DU CREUSOT (S.F.A.C.)	CO_2 pipes and condensers
STE ALSACIENNE DE REGLAGE THERMIQUE (S.A.R.T.)	Expansion joints
NEYRPIC JANSEN	Cold CO_2 stop-valve Hot CO_2 stop-valves
STEIN & ROUBAIX	CO_2 filtration
STE ALSACIENNE DE CONSTRUCTIONS MECANIQUES (S.A.C.M.)	Diesels, compressors and instrumentatio
ALSTHOM	Turbogenerator unit
BERGERON	Circulating pumps
CIE INDUSTRIELLE DES TELEPHONES (C.I.T.)	Data logger
INTERTECHNIQUE	b.s.d. data processin
APPLEVAGE	Turbine house gantr crane
ETS VOYER	Reactor travelling crane
STE MERLIN-GERIN	High and low voltag electrical apparat

This drawing, copyright NUCLEAR POWER, was published in the April, 1960, issue. Copies are available at 2/6 (post free)

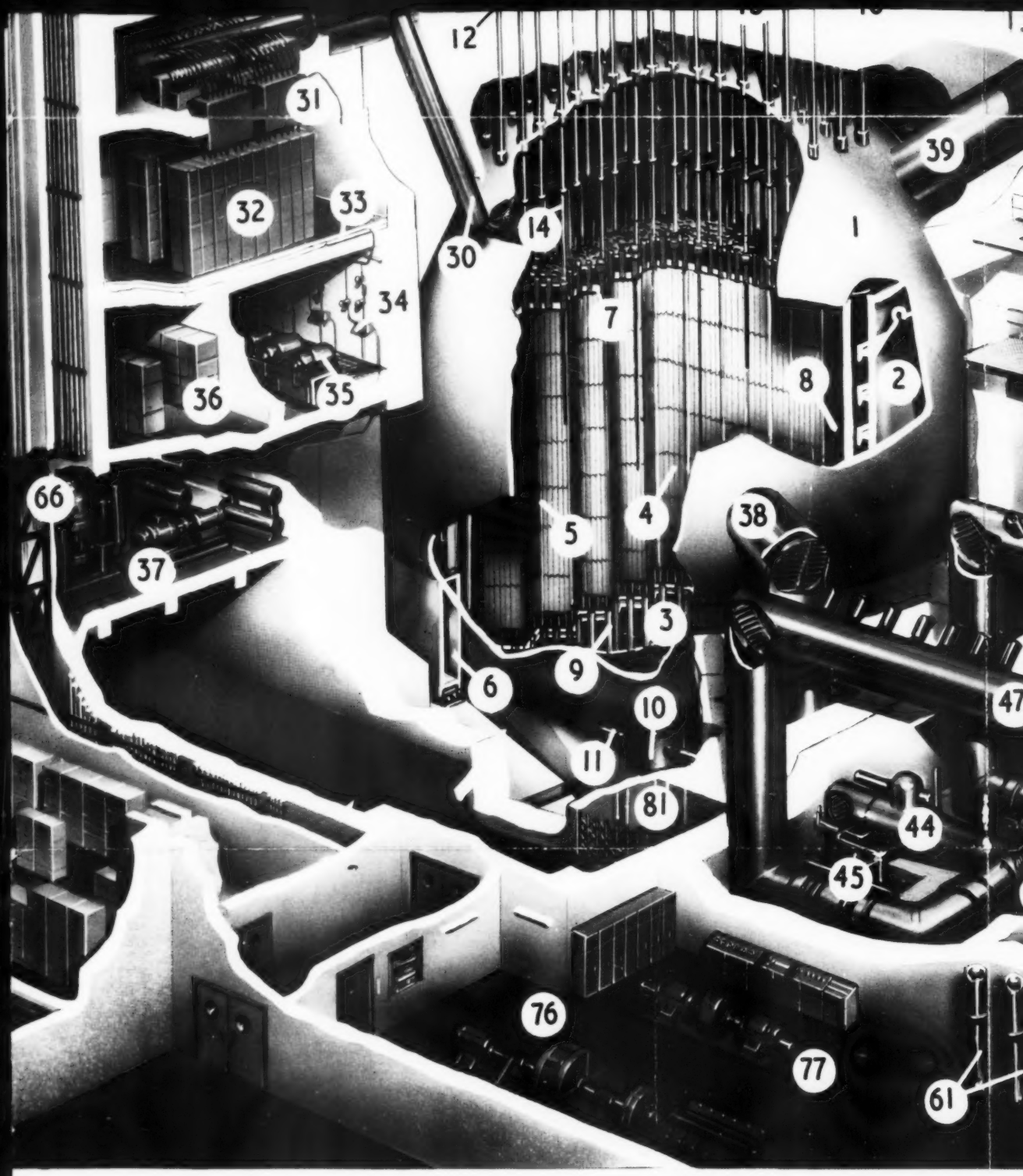
Nuclear Power
REACTORS MATERIALS INSTRUMENTATION PROCESSES IRRADIATION

NUCLEAR POWER is published monthly. Annual subscrip costs £2.2.0 UK and overseas (US and Canada $8.00). Stud £1 ($3.00). Write to Rowse Muir Publications Ltd., The Ro Muir Building, 77-79 Charlotte Street, London, W1, Eng

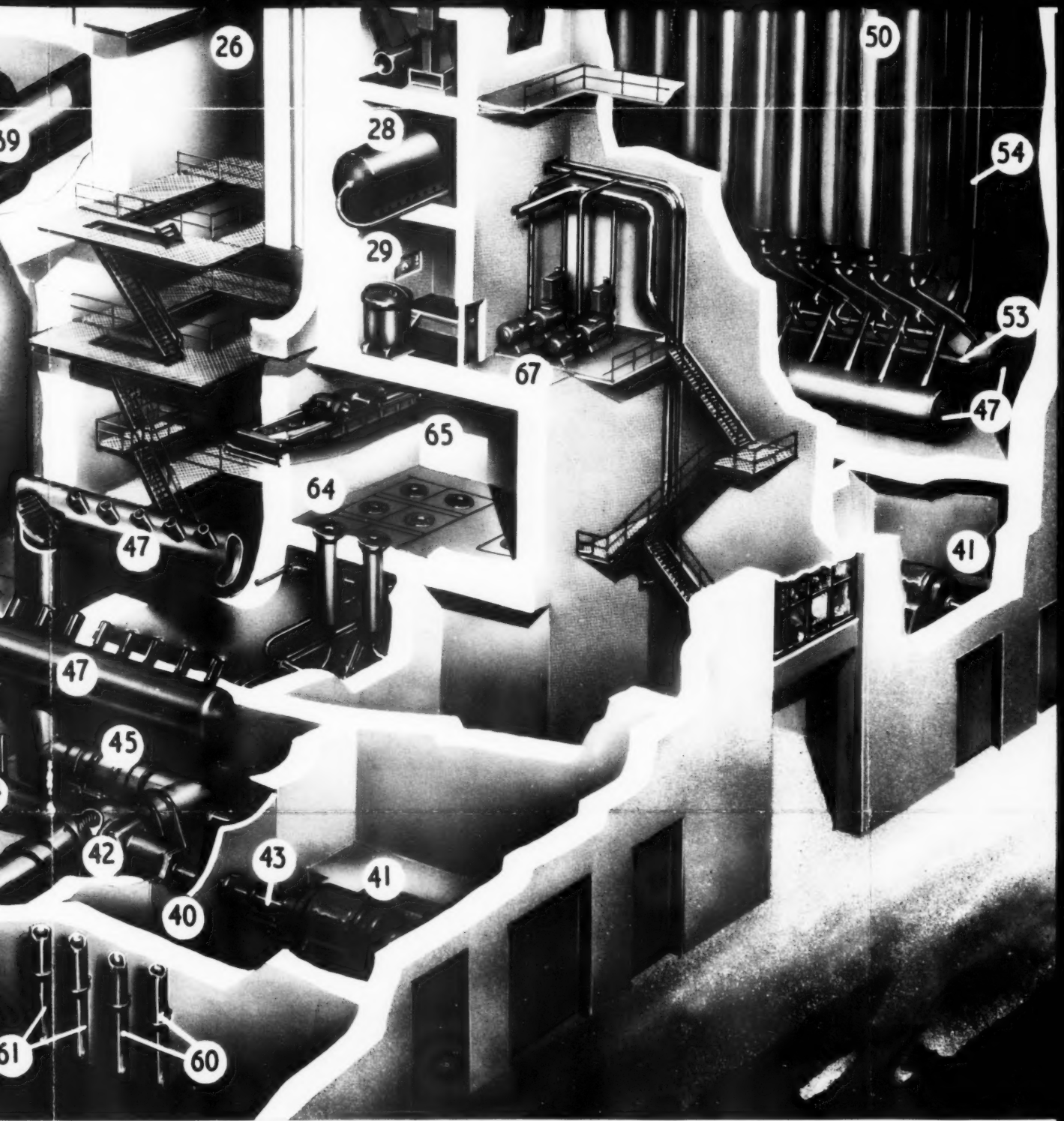


Key to drawing

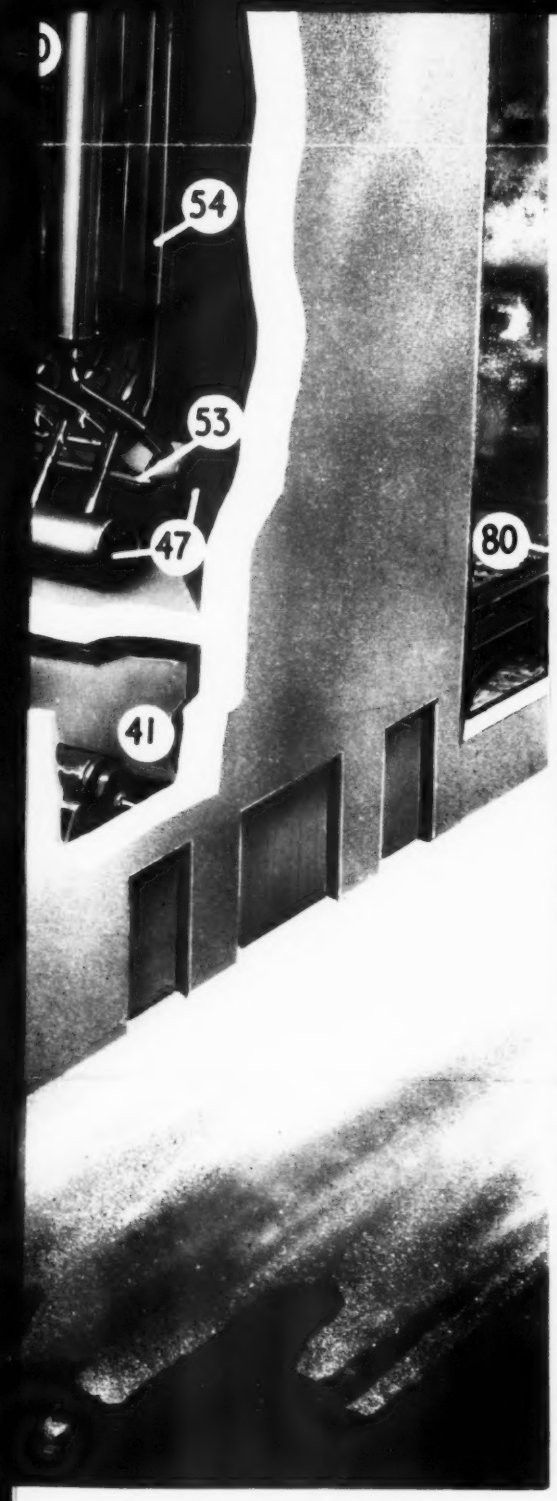
1 Spherical pressure vessel
2 Primary gas seal
3 Diagrid
4 Reactor core
5 Fuel elements
6 Reactor support
7 Charge pans
8 Graphite reflector
9 CO_2 flow control
10 Debris collector
11 Debris collector access pipe
12 Charge/discharge standpipe
13 Control rod standpipe
14 Control rod
15 Control rod winch room
16 Biological shield
17 Secondary biological shield
18 Stock pit for control rod winch
19 Decontamination pit for loading chute
20 Turning bridge
21 Charging hole preparation machine



22 Main charge/discharge machine
23 Travelling crane (15 tons load)
24 Refuelling control room
25 Electrical apparatus room for charge machine
26 Loading devices decontamination room
27 Decontamination room ventilation
28 Filtered CO_2 feed tank
29 Decontamination solutions preparation room
30 Burst slug detection pipes outlet (b.s.d.)
31 Primary b.s.d. coolant
32 b.s.d. selector valves
33 Secondary b.s.d. coolant
34 b.s.d. filter
35 Precipitator unit
36 b.s.d. electrical apparatus cubicle
37 b.s.d. compressors
38 CO_2 inlet duct
39 CO_2 outlet duct
40 Blower biological shield
41 Blower motor electric drive
42 Blowers (4 off)
43 Hydraulic coupling
44 Stop-valve
45 Expansion bellows



46 CO_2 inlet header
47 CO_2 outlet header
48 Superheaters, H.P. and L.P.
49 Evaporator H.P.
50 Evaporator L.P.
51 H.P. drum
52 L.P. drum
53 H.P. water collector manifold
54 Inlet water duct in L.P. economizer
55 Feed water header of H.P. superheater
56 Water discharge pipes from economizer to L.P. drum
57 Water discharge pipes from economizer and evaporator to H.P. drum
58 Outlet pipes from L.P. superheater
59 Outlet pipes from H.P. superheater
60 H.P. steam header
61 L.P. steam header
62 H.P. steam chest
63 L.P. steam chest
64 CO_2 purification filter
65 Filters (64) handling room
66 CO_2 purification apparatus
67 Exhauster for CO_2
68 Shield cooling fan
69 Exchangers handling hoist
70 Power plant control
71 Control desk
72 Data loggers
73 Main switchboard
74 Secondary switchbo
75 Electronics room
76 Diesel engines
77 Synchronous motor
78 Turbine room gant
79 Connecting cables control rooms (70)
80 Cooling pond for i
81 b.s.d. access lift



la soufflante
42 Soufflantes (4 semblables)
43 Coupleur hydraulique
44 Obturateur
45 Soufflet de dilatation
46 Collecteur d'arrivée du CO_2 à l'échangeur
47 Collecteur de sortie du CO_2 de l'échangeur
48 Surchauffeurs H.P. et B.P.
49 Vaporisateur H.P.
50 Vaporisateur B.P.
51 Ballon H.P.
52 Ballon B.P.
53 Collecteur d'eau H.P.
54 Collecteur d'arrivée d'eau dans l'économiseur B.P.
55 Collecteur d'alimentation du surchauffeur H.P.
56 Tubes de sortie d'eau de l'économiseur vers le ballon B.P.
57 Tubes de sortie de l'économiseur et du vaporisateur vers le ballon H.P.
58 Tubes de sortie du surchauffeur B.P.
59 Tubes de sortie du surchauffeur H.P.
60 Collecteur de vapeur H.P.
61 Collecteur de vapeur B.P.
62 Barillet de vapeur H.P.
63 Barillet de vapeur B.P.
64 Filtre du circuit d'épuration du CO_2
65 Salle de manutention des filtres (64)
66 Appareils d'épuration du CO_2
67 Extracteur pour la vidange des circuits CO_2
68 Ventilateurs du circuit de refroidissement de la protection du réacteur
69 Treuil de manutention des échangeurs
70 Salle de commande de la centrale
71 Pupitre de commande
72 Télescriptrices
73 Tableau principal
74 Tableau secondaire
75 Salle d'électronique
76 Groupes diesels
77 Groupe synchrone
78 Portique roulant de la salle des machines (50 T)
79 Câbles de liaison entre les deux salles de contrôle (70) (24)
80 Piscine de désactivation de l'uranium irradié
81 Monte-charge d'accès à la d.r.g.

70 Power plant control room
71 Control desk
72 Data loggers
73 Main switchboard
74 Secondary switchboard
75 Electronics room
76 Diesel engines
77 Synchronous motor
78 Turbine room gantry crane (50 tons)
79 Connecting cables between the two control rooms (70) (24)
80 Cooling pond for irradiated fuel
81 b.s.d. access lift

THE REACTOR

The concept is similar to that of EDF1; tubular fuel elements; flattening without absorbers; vertical channels; steel pressure vessel. The most important differences are; higher fuel element temperature; graphite sleeves; hexagonal lattice; spherical pressure vessel; charge and discharge on load —as in G2 and G3.

A large reserve of reactivity is provided so that small additions to the uranium can be made to achieve improvements in its behaviour under irradiation.

Optimization studies for a given power output have been concerned mainly with (*a*) research on smallest possible size for the pressure vessel, (*b*) reduction in number of channels.

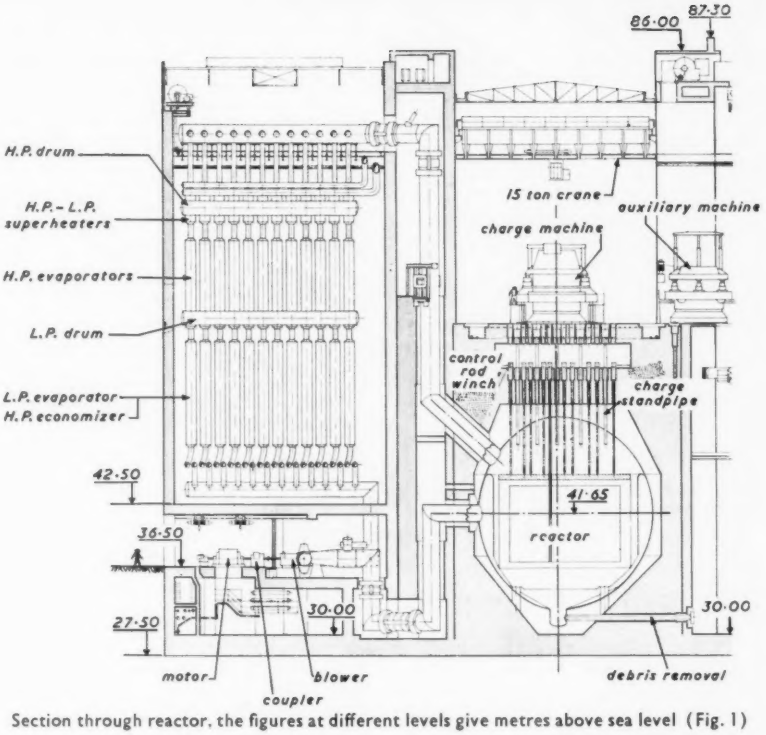
A uniform hexagonal lattice was adopted for constructional reasons; it has a pitch smaller than the optimum. Each refuelling standpipe serves a hexagonal area, and there is a control rod channel at each of the corners of these hexagons.

Neutron flux flattening is obtained by the introduction of excess uranium into the centre part of the core instead of using absorbers as in the classical method. For a given reactivity this method has a better ratio of average to maximum flux. In the centre region all the available channels are filled with fuel. Outside this region, in a regular manner, a certain proportion of channels is left empty, so as to give an optimum 'semi-regular' lattice. This arrangement is more flexible than that of EDF 1, as the layout can be changed whilst the plant is running. An intermediate zone can reduce the flux surge between the centre and the peripheral zone.

The fuel element is a tube of slightly alloyed uranium with an outer can of magnesium-zirconium. The exact can shape has not yet been finally settled but this will be decided on the results of tests carried out on the CO_2 loops at Saclay and the EDF laboratory at Chatou (see M. Stohr's article p. 133 of this issue).

Each channel contains a stack of 12 identical elements. Dummy cartridges, upper and lower, ensure complete continuity of the corresponding reflectors. The flow rate is regulated by a gag fitted at the base of the channel.

The stacking principle gives a constant lattice spacing in which the channels are maintained linear, in spite of variation in brick size, which can be in opposite senses along the length of a column with expansion at the bottom and shrinkage at the top. It is found that by a brick and key system spacing remains constant throughout the whole height of the stack whatever the distortions in the graphite. (see Fig. 2). Its form is determined by that of its base.

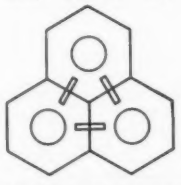


Section through reactor, the figures at different levels give metres above sea level (Fig. 1)

A support structure, made of steel columns traversing the peripheral reflector bricks, ensures the cohesion of the whole assembly. The steel columns are tied together at the top by low-expansion steel chains, to equalize the expansions of the upper and lower sections of the stack.

Pressure vessel

The flattened shape of the reactor core has led to the adoption of a spherical shape for the pressure vessel. The total number of penetrations necessary for various pipes is about 230, besides the 8 CO_2 ducts. A



Brick and key system of stacking (Fig. 2)

partition to separate cold and hot gas is provided inside the vessel. The main characteristics of the pressure vessel are as follows:

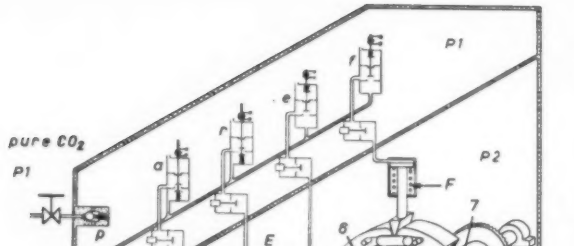
Operating pressure 355 lb/in²
Top vessel temperature 380°C
Bottom vessel temperature 196°C
Internal diameter 60 ft
Wall thickness 3⅝ in.
Steel: ASTM 302 Grade A slightly modified.
Support by means of 14 columns on a circumference of 53 ft dia.

After general stress-relief, the vessel will be subjected to a hydraulic test with inhibited hot water.

Fuel handling

Charging is from the top on load. The full equipment consists of four machines which together handle all materials which enter the reactor, including, for example, control rods. The standpipe closure and shielding plug are first dealt with by a hole preparation machine which serves two independent charge machines. A fourth machine is intended principally for unusual events and emergencies. All these machines (about 500 tons each) move in turn across the pile cap on a rotating gantry to serve the 85 standpipes. The pile cap shield is split to improve the shielding during fuel handling. The height of the hole preparation machine is about 40 ft and the charge machine is 23 ft high. The shielding for both machines is of concrete and attached in such a way that, for maintenance purposes, it can be separated from the working parts which are lowered through a port at pile cap level, arranged so as to retain the shielding.

The sequence of operations for charging is as follows: the upper shield plug is withdrawn from the pile cap by crane, and the hole preparation machine brought into position



Control rod drive (Fig. 3)

after a blind flange on the standpipe has been removed. A gas seal is made by the machine between itself and the standpipe, and the lower shield plug withdrawn so that the charge chute which at this time carries a shield plug may be inserted with its valve closed. The hole preparation machine is moved away and the charge machine brought into position by the gantry. It is an important feature of the chute that a complete fuel channel may be dealt with without any further chute setting.

The charge pans, unlike British practice, are of similar dimensions in plan to the graphite bricks.

Main circuits

A dual pressure steam cycle has been adopted. The reactor inlet CO_2 temperature has been selected to avoid undue Wigner Energy storage.

In order to assure adequate water cooling at all times, the CO_2 circuit has been designed to give a degree of natural circulation when the blowers are shut down. Dump condensers are provided to accept steam under emergency conditions and to assist with starting up and shutting down. The essential auxiliaries are driven from quick-start diesel generators.

The four heat exchanger batteries each comprise 24 vertical towers arranged in two banks of 12. The bases are elliptical and take all the water, steam and CO_2 connexions. Each tower is supported at the top and can expand downwards.

The CO_2 circuits are similar to those of the main EDF1 plant. Auxiliary CO_2 circuits are provided for b.s.d., filling, sealing, filtering and blowdown. The pressure in the main circuits is 355 lb/in² and the temperature ranges between 190° and 365°C.

One blower unit, comprising blower, variable speed hydraulic coupling, and motor is provided for each heat exchanger battery. The driving shaft of the blower is sealed with carbon dioxide at a pressure greater than that of the main circuits. The blower is driven by a three-phase induction motor.

Large diameter ducts are used with slight variation in diameter and thickness according to their location. The different diameters have been selected to reduce blower power to an economic minimum. The gas velocity is in the region of 60 ft/s. The expansion joints are of the bellows type and their number and location has been chosen to minimize reaction on the reactor vessel, heat exchangers and blowers. Butterfly-type valves, operated by CO_2 are provided in each circuit to isolate the heat exchangers and blowers.

Turboalternator

The turbine has four exhausts and is directly coupled to a three-phase alternator. The turbine comprises two rotors, one HP and one LP. Twin 'pannier' condensers flank the turbines. All the connexions have bellows joints to allow for expansion. Particular attention has been given to condenser design to minimize losses and achieve efficient deaeration of condensate.

The feed-water heating installation has two identical stages, both are fed with steam from the turbine at pressures of 11·8 lb/in² and 2·16 lb/in² respectively. Two 100% duty extraction-pumps supply condensate to the LP and HP feed pumps.

It has been foreseen that dump valves will be necessary for both HP and LP circuit so that steam can bypass the turbine and be sent directly to the condenser. This device facilitates start-up and shut-down operations.

Control rod drives

Investigations have shown that 100 control rods are necessary and provision has been made for 110. From analogue computer calculations it was decided that 8×10^{-5} in k (8 pcm) is required to ensure a sufficient speed of response in the reactor.

Considerations of speed, robustness, and security have led to experiments being made with a view to finding a pneumatic drive, using the difference in pressure of 150 lb/in.² between the main which supplies gas to the blower seals and other points and the reactor space (Fig. 3).

Results of the tests carried out under working conditions show that continuous working for 2000 lifts and free falls can be achieved. This would correspond to the performance under the most frequent use during the life of the reactor. It is still possible, during the running of the reactor under power, to get at the components which are subject to wear or to getting out of order, and even to change the whole mechanism completely.

The absorber used is sintered boron carbide. A device allows the drive to be disconnected from the rod when the latter is resting on the base of the reactor, thus simplifying handling by the unloading apparatus.

Control

The general control adjusts the neutron flux to the energy taken by the turbine by giving the control rods a certain speed. When these latter reach the end of their run, they set in movement shim rods, to allow the control rods to return to their normal settings.

The shim rods are divided into two groups: a first group of about 80 rods; and a group of 24 rods, each of which receives the following orders. (*a*) a general 'compensation' order (*b*) an individual order, based on information from the reactor controlled by the rod, with a view to reducing the oscillations caused by the xenon buildup.

During normal working, the first group is in the up position, the compensation orders mainly concern the 'xenon' group; this does not appreciably disturb the flux shape, bearing in

mind the small number of rods involved.

Neutron flux measurements

Three types of measurement circuit are provided. Two starting circuits measure the power under subcritical conditions. These circuits are used mainly during initial startup operations. There are also three logarithmic-response circuits with associated period meters measuring the power from about 100 W to 1000 MW. One of these circuits is used for coarse control of the reactor. A discrepancy system selects and eliminates a circuit that may be defective. Finally there are three non-electronic excess or safety circuits for stopping the reactor if the power exceeds 1000 MW.

The measurement chambers are located between the biological shield and the pressure vessel. Six positions are arranged symmetrically in a horizontal plane and six positions without lead shielding are provided side by side with the foregoing.

The pre-amplifiers are in the top biological shield some 20 ft above the chambers. The rest of the electronic apparatus is accommodated in the electronic equipment room next to the control room.

Graphs of typical neutron flux and other measurements are shown in Fig. 4.

Burst slug detection

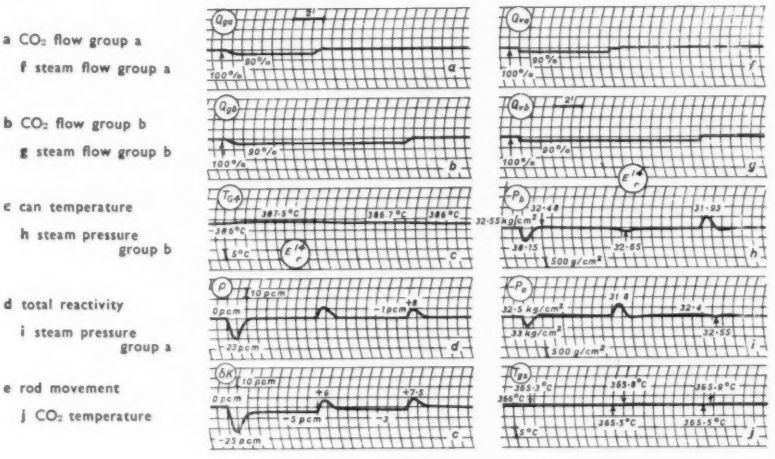
Gas circuit A gas sample is taken from each of the reactor channels by means of stainless steel tubes (60 miles of tubing are used).

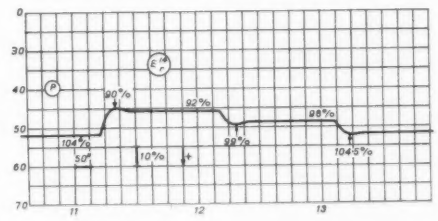
After emerging from the pressure vessel the tubes are cooled and are carried to rotating selectors, which group the gas from eight channels. The gas then goes to selectors, and after further cooling and pressure filtration to remove all solid particles, it is delivered in accordance with a predetermined cycle at the precipitator inlet. The precipitators use a drum electrode to collect the positive solid ions, the measurement cycle comprising (a) application of high tension to the electrode, and (b) angular displacement of the drum to the counting position. The drum is driven by an external motor coupled magnetically through the casing. The selecting system comprises: 300 rotating selectors, 70 electric valves, and 3000 manually operated isolating valves.

Under normal conditions this network allows the analysis of gas samples from eight grouped channels. If the adjustable threshold of activity is passed the eight doubtful samples are separated and individually analysed at an accelerated rate to ensure rapid identification of the defective channel. Analysis cycle periods are 26 minutes in the normal case and 8 minutes for identification purposes.

Under normal conditions the activities of all the groups are recorded in a memory system for 48 hours. In the case of the EDF2 sheets of results are printed out by electric typewriters.

The whole data processing equipment comprises: 2 digital computers connected in parallel to increase reliability ; 6 cubicles containing the whole of the electrical equipment ; 5 electric typewriters for recording purposes ; 2 extra electric typewriters ; and some 2000 relays. This equipment is described on p. 126.


a CO_2 flow group a
f steam flow group a
b CO_2 flow group b
g steam flow group b
c can temperature
h steam pressure group b
d total reactivity
i steam pressure group a
e rod movement
j CO_2 temperature



Graphs of neutron flux and various flow measurements (Fig. 4)

Instrumentation in the control room

The equipment used is of the 'miniature' type. The size of the indicators and the control knobs is 20 in. × 2 in. and that of the recorders 6 in. × 6½ in. The recorders are mounted on a vertical panel and all the other apparatus on a panel inclined at an angle of 15° to the horizontal. As a rule the controller faces his desk.

Controls The controls are effected by means of push-buttons, illuminated turn and push-buttons (TPL), switches, manual control relays, etc. There are 260 of them on the desk and 130 on an auxiliary panel. (see Table 1).

TABLE 1 *Distribution of measurements transmitted to the control room*

TYPE	MEASUREMENTS INDICATED	MEASUREMENTS RECORDED*
Temperature	16	1000
Pressure	28	72
Output	17	17
Level	21	8
Mechanical (vibrations, expansions, etc.)	8	30
Position	160	0
Electrical	20	20
Health	0	70
B.S.D.	0	312
Nuclear	0	3
Chemical analysis	0	46

* The measurements are recorded on an automatic processing machine.

Relay equipment

This equipment has been grouped in a room adjacent to the control room. It is supplied by a 127 V battery charged by rectifiers connected to the emergency supply.

All apparatus, contactors and motor control circuit-breakers are controlled from a relay assembly consisting of some 3000 electromechanical and static relays.

The direct-current distribution is divided into 25 sections, each comprising about 10 sub-sections, each suppling a group of machines forming a relatively independent functional unit such as, for example, a 125 MW turboalternator set, the charge/discharge apparatus, CO_2 circuit, etc.

Automatic starting

Start-up and shut-down have been divided into distinct stages, each corresponding with a defined condition.

Passage from one stage to another is effected automatically.

The start-up and shut-down stages coincide, which enables the operation to be reversed at any point.

At the present stage in the design about 50 starting stages are provided for, and some fifteen starting conditions are envisaged according to the availability of the circuits. The selector switches for these starting conditions are in the control room.

The control equipment is connected to an assembly of automatic devices which control the relays of the various functional sections and sub-sections.

Manual controls are also provided in the control room, to enable any possible fault in the automatic starting equipment to be by-passed at any moment. Automatic starting takes the station to a power of about 10 MW; but for safety reasons complete confidence has not been placed in the automatic equipment, and the control room of EDF2 is regarded as a transition stage between the control rooms of conventional power stations and the 'push-button' control room.

General measurements

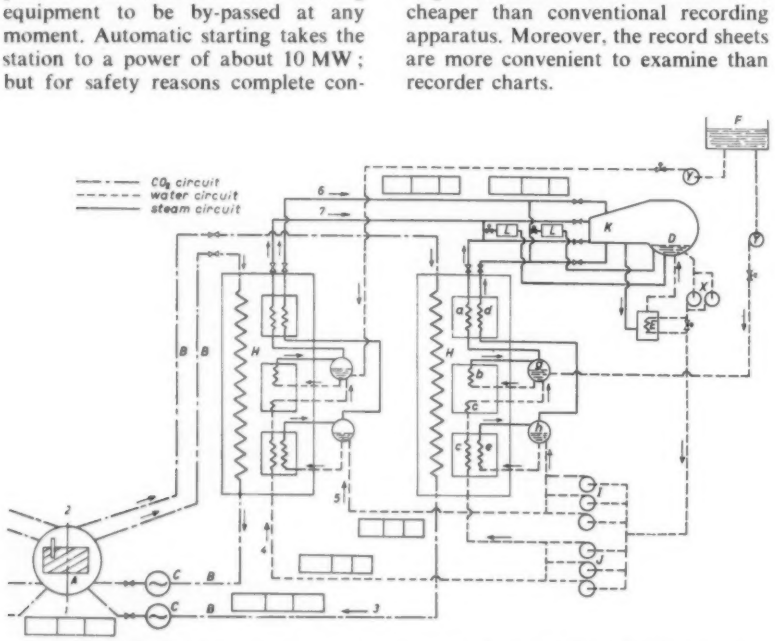
For the measurements an original solution, already tried out in EDF1, has been adopted. Indicating instruments are still provided but conventional recorders have been replaced by a data logging equipment which comprises an assembly of two switches, two coders, two digital computers and five electrical printers.

In the event of the alarm threshold being passed, the supervisory measurements taken are printed out. In parallel, on a second typewriter, a record is made representing some ten to twenty minutes. When everything has been restored to normal the operator can restore the memory circuits to normal operation.

Statistical measurements are printed out every hour on a typewriter in an annexe to the control room.

Mixed measurements The mixed measurements are those which require both the above kinds of treatment.

Some two thousand measurements are dealt with by this equipment. It has been calculated that for such a large number of measurements it is cheaper than conventional recording apparatus. Moreover, the record sheets are more convenient to examine than recorder charts.



A reactor; **B** Gas circuits; **C** Blowers; **D** Condenser; **E** Reheater; **F** Demineralized water tank; **a** HP superheater; **b** HP evaporator; **c** HP economizer; **d** LP superheater; **e** LP evaporator; **g** HP drum; **h** LP drum; **T** LP feed pump; **J** HP feed pump; **K** Turbine; **L** Dump valves; **X** Extraction pump; **Y** Feed pumps

Pressure in (lb/in^2), temperature (°C), and flow (lb/s) in different parts of the circuits are **1** 365; 198; 2420; **2** 354; 355; 2420; **3** 346; 192; 2420; **4** 546; 90; 105·6; **5** 135; 90; 57·2; **6** 124; 340; 57·2; **7** 463; 340; 105·6

Flow diagram of the water, steam, and CO_2 circuits (Fig. 5)

GENERAL OPERATING PRINCIPLES

Use of special apparatus, such as teleprinters and automatic start-up and shut-down sequences, means that it should be possible to reduce the operating staff. Experimental investigations using an analogue computer and a heat exchanger have been carried out.

Control lines are electronic, except for the servomotors, because of the speed of response required. The equipment is completely transistorized and has given satisfaction during trials carried out in a conventional station. It is also proposed that a complex control assembly of the 'non-interaction' type will be tried out for controlling reactor power and the CO_2 supply.

Operation

A method has been developed for completely automatic running, under which the action of the operator is limited to that of making certain preliminary choices of circuits, according to what is available. The various phases are as follows.

Start-up When shut down, the residual power of the reactor is dissipated by natural convection. The operator presses the button 'Start. Set 1', which sets in motion the following sequences: (*a*) heating of circuits by natural convection during which, after checking of safety circuits, the reactor control puts up the neutron power to 50 MW, (*b*) starting up of 1st set, during which the blower is started, which allows the alternator to be coupled up.

When the neutron power reaches 200 MW (which is imposed by the minimum capacity of the blowers) the operator can (by pressing on the button 'Start. Set 2') set in motion the following sequences: (*a*) putting into service the two blowers belonging to Set 2, (*b*) coupling-up Alternator 2.

Normal running The installation is subject to grid requirements, as with an ordinary power-plant. During a frequency change, the sequence is as follows: (*a*) adjustment of turbine to new frequency (*b*) change in neutron power to take into account the new steam output, and (*c*) adjustment of CO_2 flow to neutron power.

The two sets can be controlled independently by (*a*) adjustment of blower output of each turboalternator set to its appropriate power, and (*b*) allocation of output between the two blowers of the same set by means of a potentiometer controlled by the operator.

Investigations with the analogue computer show that when the two sets are connected in parallel, the plant can respond to a sudden change of 10% in demand and that it is possible to make a sudden change of 10% in the load on one set without disturbing the running of the other one.

Faults To limit thermal shocks on the fuel elements and reduce outage time to a minimum, attempts have been made to provide security in proportion to the seriousness of the trouble. Investigations with the computer have led to the following sequences. Fault in a blower: reduction in neutron power is obtained by the dropping of a control rod controlled by the faulty blower. The corresponding turboalternator set adapts itself to maintain steam pressures

within the acceptable limits. Disengagement of a turboalternator set: this is accompanied by the fall of two control rods controlled by the corresponding blowers which are also cut out. Loss of voltage in grid: the two sets continue to work on auxiliary power. Serious trouble in reactor: control rods fall in 6 seconds.

Safety

To dissipate the residual power of the reactor it is essential to have, at every moment, blower and coolant circuits. Due to the relative levels of heat exchangers and reactor, gas circulation by natural convection enables 10% of the nominal power to be dissipated whilst maintaining an acceptable temperature (Fig. 5).

HP drums can be fed as a safety measure by special pumps.

Exceeding safety threshold The operator is informed by data processing equipment in less than one minute of any parameter which exceeds the maximum specified for the plant. The neutron flux measuring devices have also three excess flux detectors which can trip the reactor on a 2 out of 3 basis.

Continuous supplies To guarantee that the above-mentioned safety measures can always be taken, emergency supplies of the following are maintained: CO_2 (for maintaining pressure and working valves), cooling water, compressed air, electricity.

CIVIL ENGINEERING

EDF2 comprises one reactor with associated steam generation plant, outdoor turbogenerator, electrical equipment and circulating water system. The main power station buildings cover an area 285·4 ft by 249·3 ft.

The pumping station is located on the South bank of the canal, and consists of two circulating-water pumps each with a capacity of 2300 gal/s and two sump pumps each with an output of 370 gal/min. Each of the main pumps is preceded by a fixed coarse screen and a rotation drum screen. The suction inlet of each of these pumps is of concrete. The cooling-water culverts for the condensers are 'Bonna' pipes and the diameter varies from 5 ft 11 in. to 6 ft 8 in. These pipes consist of a sheet metal tube covered on the inside and out with reinforced concrete. A bypass on the return culverts allows recirculation to provide sufficient output in low-water periods.

Power station

The actual power station comprises a turbine bay, a heat-generating unit consisting of; reactor, four heat exchanger batteries, CO_2 filtering plant, burst slug detection (b.s.d.), building for irradiated fuel, a cooling pond, a control room, diesel engine room and charge/discharge control room. These items are built on 9 independent rafts separated by 'Waterstop' joints to protect against infiltrating water.

Turbine bays and electrical annexe The turbine bays are separated by an electrical annexe, above which is the control room.

Reactor The spherical pressure vessel is 60·2 ft in diameter and is contained in a cylindrical shield the walls of which are 6·56 ft thick and enclosed at the top by two slabs, 11·5 ft thick and 6·56 ft thick, between which is the control rod actuator room. In order to clear the standpipes the pile cap reinforcement is in the form of a metal framework welded on to a 0·787 in. base plate.

The four heat-exchanger batteries are contained by a concrete shield wall 3 ft thick. The blowers are located at ground level and shielded from the heat exchangers by a concrete roof.

Burst slug detection The b.s.d. building is concrete framed and flanks the reactor shield. The charge/discharge control room is located above.

Cooling pond The pond comprises a rectangular basin resting on the rock. It is a strongly reinforced monolithic block and is completely watertight.

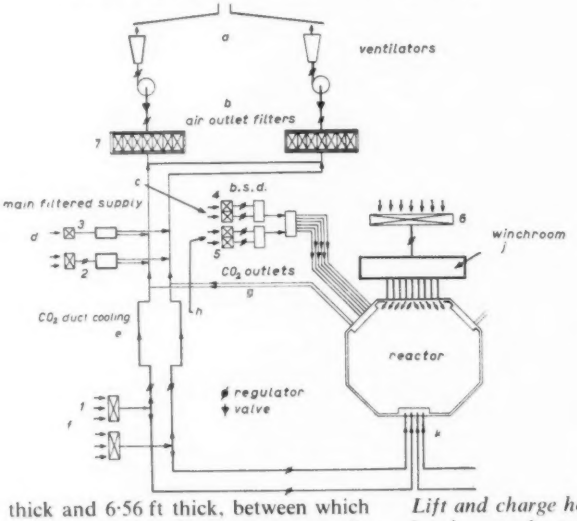
A schematic diagram of the cooling air system is shown in Fig. 6.

Mechanical handling

Travelling gantry crane This gantry with a capacity of 50t/15t and a span of 124·7 ft serves the entire generating plant. It can handle a condenser body.

Radioactive filters The main circuit filters will be handled in a depressurized room. Manipulation is effected by an electric travelling gantry operated from the outside and observed through a glass panel.

The reactor hall is of cruciform shape situated between the four heat-exchanger batteries level with the upper slab of the reactor. Two overhead travelling cranes are provided, one of 130 tons, the other of 15 tons capacity. The former is used only for handling the charge/discharge machines whilst the latter is for general purposes. The crane rails are arranged at right angles and the gantry of the heavier crane carries the centre section of the rails for the lighter one so that the gantry of the latter may traverse the whole of the pile cap.



Height above sea level, m

1	36·50
2	36·50
3	47·00
4	40·80
5	46·00
6	55·00
7	83·00

Flows, ft^3/s

a	2 × 735
b	2 × 735
c	2 × 127
d	196
e	2 × 123
f	2 × 245
g	2 × 245
h	2 × 157
i	980
j	980
k	4 × 123

Four extractor fans each of 235 ft^3/s capacity depressurize all ventilated areas. The air drawn through intakes passes through multiple oil-bath filters (Fig. 6)

Lift and charge hoist The b.s.d. building is served on the north face by a lift holding four persons and on the south face by a goods lift with automatic control capable of lifting 2·5 tons.

THE NEXT STEP

The company 'Grands Travaux de Marseille,' began building the reactor shield on October 1, 1958, this part of the work was finished in July 1959. Work on the heat exchanger shielding was finished on December 15, 1959.

The spherical pressure vessel will be fabricated on site from horizontal rings. A study of the weights involved and the problem of getting parts of the charge machines into position has led EDF to instal extensive handling equipment.

This comprises principally a 200-ton travelling crane above the reactor the tracks of which are supported from the heat exchanger shielding and are extended over the cooling pond. The pond suitably roofed will serve as a prefabrication workshop for sections of the reactor vessel. Construction of the heat exchangers begins in April 1960 and that of the turboalternators in June 1960. The station will be commissioned 1962.

ATOMIC ENERGY
IN FRANCE

A survey of recently developed French instruments shows continuing interest in miniaturization

Trends in French reactor instrumentation

Edited by M. SURDIN
Head of the Electronics Division, CEA

THE ELECTRONICS DIVISION is responsible for research and development as well as for theoretical studies of the large number of electronic instruments used in the atomic energy field. The Division has a number of branches for general electronics, applied electronics, physical electronics, industrial electronics, and radioactive element measurement. The Division also acts as adviser to the CEA and industry.

Reactor control

by J. WEILL,
Head of Reactor Instrumentation Section, CEA

THE three essential lines of development in reactor control in France are: (*a*) transistorization of equipment, (*b*) digitalization of information, and (*c*) increase in automation and safety measures.

Neutron detectors

Transistorization or the use of magnetic amplifiers necessitates the use of very sensitive detectors, due to the fact that they are in general less sensitive than the usual valve assemblies. To that end, new ionization chambers have been developed.

In the field of compensated chambers, a new multiple plate chamber with 400 plates gives a sensitivity of 10^{-12} A for a flux of 1 n/cm²/s. As the γ-compensation factor is of the order of 300, filling this chamber at 6 kg pressure (13¼ lb) gives a distance between plates of the order of 1 mm (0·039 in), the overall length being 80 cm (31½ in.) and the diameter 10 cm (3⅞ in.). In the field of non-compensated chambers, with the same chamber volume as the previous one, a sensitivity of 10^{-11} A/n/cm²/s is obtained.

Furthermore, a type of fission chamber has been developed with a sensitivity 0·15 pulses for a flux of 1 n/cm²/s and capable of operating at a temperature of 600°C.

Electronics

A few examples of recent developments are:

(*a*) D.C. logarithmic amplifier with 8 decades from 10^{-13} to 10^{-5} A and giving quick response when subminiature valves are used.

(*b*) D.C. logarithmic amplifier with 7 decades, using an electrometer valve and a magnetic amplifier.

(*c*) Differentiator for period meter. Fitted with subminiature tubes, this differentiator has a circuit which may be adjusted according to the desired response curve. Moreover, the use of non-linear elements, such as diodes, enables the noise to be limited whilst at the same time retaining a high speed of response (a few tenths of a second).

(*d*) D.C. linear amplifier, entirely transistorized, which allows of measurements being taken over the whole scale from 10–1–0·1 mA; the drift is $0{\cdot}5 \times 10^{-10}$ A/°C and $0{\cdot}5 \times 10^{-9}$ A/day.

Measuring equipment

Two typical examples of how this is done will be given.

Digital millivoltmeter with 50 channels This instrument automatically records on a teleprinter digitalized information coming from 50 similar sources, which can be either thermocouple signals, the results of thermocouple indications, or the results of readings translated into millivolts.

It is sensitive to 0·25 °C or 10 microvolts. Four significant figures are given for each reading and the time for scanning and recording the whole set of 50 readings is 200 seconds.

Xenon reactionmeter, predictor, and calculator Coupled to a reactor by a power measuring link this apparatus is an analogue computer. The controls are arranged in such a way as to allow the recording of the actual reactivity of the reactor at the given moment (and not the rate) on a linear scale of which the maximum value can be as small as 0·3% reactivity. The apparatus calculates the value of the xenon poisoning, in actual time, in 10 minute sequences and, in accelerated time (× 1000), the future evolution of xenon in case of total stoppage or of drop in power of the reactor.

This allows control rods to be put into position so that, when the reactor is shut down, there are always values of negative reactivity compatible with safety on the one hand and speedy re-starting on the other.

Safety circuits and elements

In the safety field steps have been taken to produce an automatic shut-off rod. Contrary to the methods adopted elsewhere, which rely essentially on the melting of a cap-

sule to trigger off the filling of an empty space with a gas which is very absorbent to neutrons, the type now being developed is based on percussion obtained from a tumbler system originating from a twin-strip heated either by excessive temperature or excessive neutron flux, the strip being coated with a uranium deposit. This purely mechanical device has the advantage over previous methods of being able to recharge itself after release as soon as the temperature and flux come back to normal.

In the field of safety circuits the tendency is to use logical circuits with magnetic-core or transistor techniques. The mechanical relay elements are then replaced by static relays. The essential advantage of choosing this type lies in the increase in robustness and in the increased speed of response.

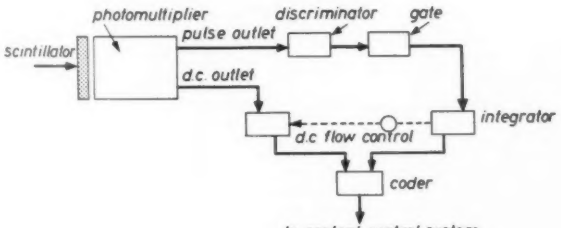
For this reason a series of logical circuits has been developed, using diodes and transistors, with a response time of 50 μs. This performance allows the logical circuits to be combined in series, giving a final response-time consistently below one millisecond. These circuits are preceded by transistor trigger circuits with a 100 mV threshold.

Being quite light, these logical systems serve both as warning and pre-warning circuits for reactors as well as for the various interlocking circuits which it is advisable to install in every nuclear power plant.

Processing health physics measurements

by E. PICARD,
Engineer, General Electronics Section, CEA

THE instrumentation available for health physics measurements must comply with the usual specification for safety devices in constant working. One difficulty should, however, be pointed out, which is due to the standards in use: the range of measurements covers five to six decades from the tenth of the maximum permissible dose up to 10^4 to 10^5 m.p.d.

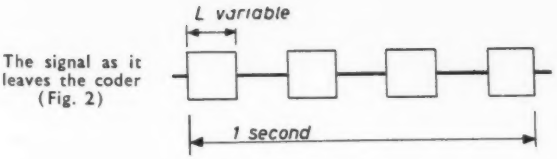


Block diagram of the detection assembly for pulse and d.c. measurements (Fig. 1)

Most existing apparatus cannot give this with a single detector, even with logarithmic amplifiers. Moreover, the results of readings must be constantly available at the control panel.

A centralized system is therefore necessary and the transmitting equipment should be as reliable as possible.

The apparatus described below solves this problem of spread of measurements and of their coding with short



or long distance transmission. Detectors of gamma rays, beta rays or neutrons (the last only come into account for 3 decades) are of a standard type of scintillator and the output levels have been standardized so that the coder remains the same whatever the nature of the radiation.

Pulse and d.c. measurements

The d.c. current, set up by the whole detecting apparatus does not reach a value suitable for direct measurement until 1000 doses of gamma and beta rays have been detected. Two detector outputs are therefore provided, which change over from one to the other when 1000 doses of radioactivity have been reached. The information given by the photomultipliers in pulse form is used up to 50,000 counts/s, which corresponds to 1000 doses. The first four decades are measured in pulses, and subsequent ones in d.c. There may possibly be some overlapping in the region of 1000 doses. A schematic diagram of the detection assembly is shown in Fig. 1.

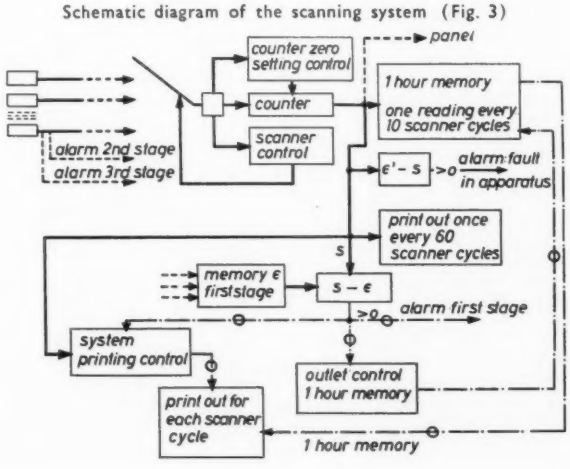
In the coder, the duration of a constant telephonic frequency sinusoidal wave train is modulated. The period of this train represents the amount of the dose, to within a multiplying factor, which is, itself, applied separately on leaving the coder. The central system has then only to count the number of sinusoids contained in the signal and to multiply the result by the multiplying factor. The signal as it leaves the coder is shown in Fig. 2 and it can be seen that the information is available 4 times per second.

Data processing

Definition of alarm levels Three alarm signalling circuits are provided for 3 different levels of activity:

ALARM STAGE 1: Activity reaches a value of the order of one third of a dose (this first threshold can be adjusted if necessary)
STAGE 2: Activity reaches 10 times the dose
STAGE 3: Activity reaches 1000 times the dose.

Schematic diagram of the scanning system (Fig. 3)



Scanning system A schematic diagram is given in Fig. 3. Coming from 60 measuring points, 60 lines bring the information to a scanner. The primary cycle of the scanner comprises: zero setting: successive counts: changeover to the following measurement.

Since the recurrence frequency is 4 per second, the scanning time given to each line is equal to 1 second. As the scanning cycle covers 60 points, it will have a period of the order of one minute.

Exceeding the threshold In case the base limit is exceeded, information is printed out every minute. If necessary at any time, readings are available 4 times per second.

Burst slug detection

by P. DESNEIGES,

Head of the Applied Electronics Section, CEA

IN French plants of the homogeneous type, and particularly for EDF reactors, methods of burst slug detection have been adopted based on the detection of solid daughter products of xenon and krypton isotopes.

Moreover, as cooling is done by gas under pressure in closed circuit, fear of pollution of the reactor channels has led us to study the evolution of the amount of fission gases present by inserting an 'evolumeter' in the b.s.d. electronic circuits.

In the b.s.d. installation in EDF2 the 2496 reactor channels are assembled in 312 bundles of 8 channels, grouped in turn into 13 assemblies corresponding to the 13 standard scanners; see Fig. 4. The 24 bundles forming one group pass one by one on to a single collector, which leads the gas of the 8 mixed channels towards the corresponding prospector. This prospector consist of a detector followed by electronic apparatus. The assembly of the 13 scanners is controlled by a digital computer of which the programming is flexible enough to be able to carry out all the necessary operations.

A measuring device connected to the bundle of 8 channels covers the following 3 steps:

1. Measurement of background B, duration 15 s
2. Collection of solid products Rb and Cs on the detector area, duration 30 s
3. Measurement of background and contamination on this area of detector $G + B$, duration 15 s.

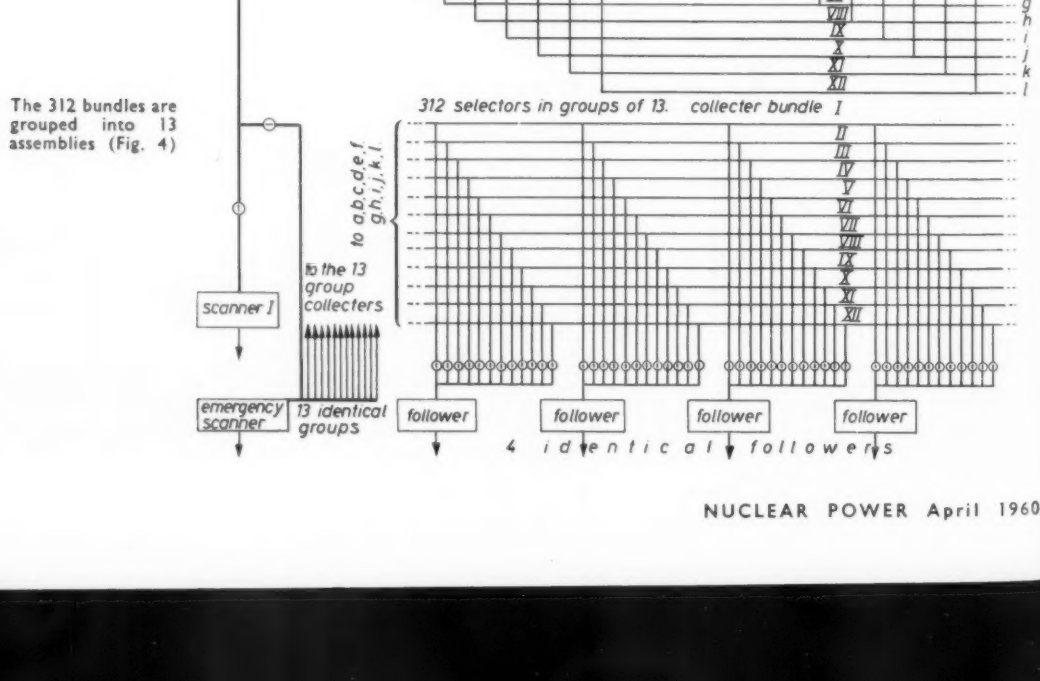
The operation carried out by the computer is of the form $(G + B) - B$, which represents the signal corresponding to the fission products corresponding to the bundle in question.

If this signal is below a given threshold, the scanner passes on to the next bundle. If not, the searcher is replaced by a follower, the function of which is to detect the duct (from amongst the 8 channels) which is leaking and to follow the development of the leak.

Actually, the calculator works on the signal G by multiplying it by a factor $1/a$ depending on the condition of the reactor, its power, age of the fuel etc., and by subtracting $G/a - G_0/a_0 = E$

where a_0 and G_0 are the standard values fed into the memory of the computer. The values a and a_0 are obtained by means of an instrument giving the power of the reactor.

The computer used is an RW300 made under licence by the Société Intertechnique and the value of E is obtained with an accuracy of the order of 1%. Safety precautions have been specially stressed. In particular, two computers are used and these work simultaneously. The electronic apparatus, completely transistorized, is checked every 24 minutes by a special programme.


1st group
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
group collecter 1
collecter bundle I
a b c d e f g h i j k l
II III IV V VI VII VIII IX X XI XII
The 312 bundles are grouped into 13 assemblies (Fig. 4)
312 selectors in groups of 13. collecter bundle I
to a,b,c,d,e,f, g,h,i,j,k,l
to the 13 group collecters
scanner 1
emergency scanner
13 identical groups
follower
follower
follower
follower
4 identical followers

ATOMIC ENERGY IN FRANCE

A year's experience with G2 has thrown some interesting light on designs for charging and discharging on power

Fuel handling on the plutonium reactors

by G. DEROME *and* A. ERTAUD
Sté Alsacienne de Constructions Mécaniques

THE French power reactors G2 and G3, built at the Marcoule centre, compared to other industrial reactors in service before them, have two original features: the use of a shield made of prestressed concrete that serves as a housing under pressure; and a loading and unloading system designed so that it can function when the reactor is running at its maximum power. Figure 2 shows the reactor and charge machines.

Fuel manipulation

Since one of the rounded ends of the shield had been used to run the large CO_2 pipes through, access to the channels could only be gained from the other end. Each channel was extended through the shield by a tube that serves the double purpose of introducing the fuel elements and regulating the flow of coolant gas (Figure 2). Each of the 1200 tubes is obturated under normal conditions by a plug that ensures perfect tightness as well as biological protection. The plug itself, roughly 19·5 ft long, is lengthened by a ramming-head that butts up against the youngest fuel element in the channel.

Using chamberlocks, new fuel elements are inserted into the tubes. Each element then pushes forward the whole train, forcing an exhausted element out at the other end. If two-thirds of the elements are renewed at each loading operation, a uniform rate of irradiation is obtained without difficulty, within a very small percentage variation.

Insertion of fresh fuel elements

The extreme overall length of the plugs (26 ft 3 in.) necessitates long loading machines. These are equipped at their front with a magazine made up of a barrel with 17 chambers each of which can hold two fuel elements. One of these chambers must be empty at all times so that the plug which is to serve as ram-rod can be pulled out. In the loading operation elements are inserted into the reactor successively by two's and the feeding barrel of the loading machine turns 1/17 of a turn between each charging. Before this cycle begins, the machine is emptied of air and filled with carbon dioxide at a slightly higher pressure than that of the reactor. When the loading is finished, normal atmospheric pressure is restored.

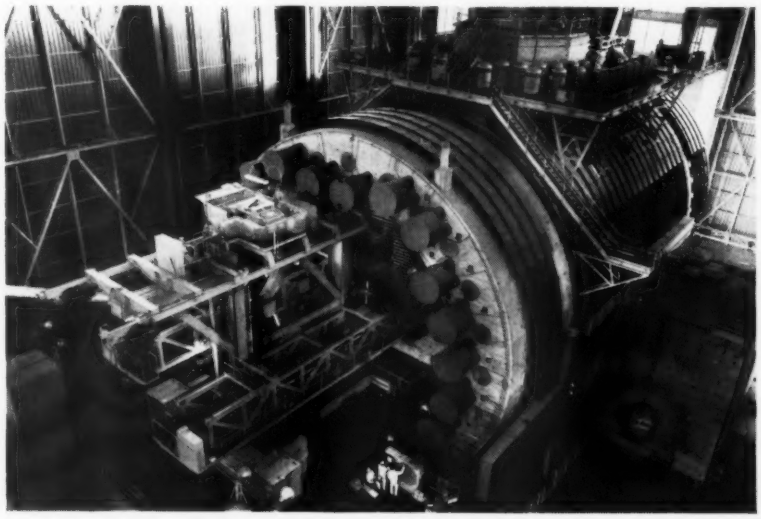
When the machine has been lined up with one of the channels and has 'swallowed' the corresponding plug, it is exposed to radiation from the core, the fuel elements in the magazine, and from the end of the plug. Strong protection is thus necessary, most of which consists of heavy concrete of specific gravity 4·5, weighing 56 tons per machine. The shape of the dome in which the loading apparatus is housed also restricts the operational possibilities of these cumbersome machines (length: 42 ft 8 in., dia. 5 ft 3 in. around the barrel). The channels have therefore been divided into two zones each served by a separate machine.

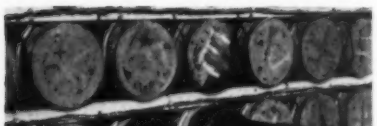
The two loading machines are carried on bridges suspended from a single heavy crane and connected by

THE REACTORS

Each reactor produces over 200 MWt under normal conditions of flattened flux. There are 1200 channels each holding 28 fuel elements 11·8 in. long. Total fuel weight is 110 tons of natural uranium. The moderator and reflector form a mass of 1200 tons of graphite. There are 100 tons of carbon dioxide in the cooling circuit at a pressure of 213 lb/in^2. Biological protection is made up of a horizontal prestressed concrete cylinder 45 ft 11 in. long and 9 ft 10 in. thick sealed at both ends with hemispherical caps.

This view of G2 shows the loading face and charge machine assembly (Fig. 1)





This arrangement of coaxial tubes for inserting the fuel elements also regulates the coolant flow (Fig. 2)

powerful chains so as to balance each other. The central structure is a vertical box-girder framework perpendicular to the loading face. This framework rests on a wide base equipped with 16 wheels that enable the whole thing to be moved horizontally parallel to the loading face. The vertical movement is effected by the suspension chains. The overall weight of the crane and the two machines is 300 tons.

Unloading the core

At the other end of the channels irradiated fuel elements are expelled and tumble into flattened conduits. Each of these conduits communicates with the channel ends that lie along a 45° diagonal. A great deal of research was necessary to work out an arrangement that would ensure the correct pivoting of the elements and keep them from getting stuck in the openings of the funnels that lead from the conduits to the evacuation tubes (Figure 3). The action of guiding deflectors was combined with the slanting effect produced by rotating the whole conduit around the axis that joins the centres of the channel outlets.

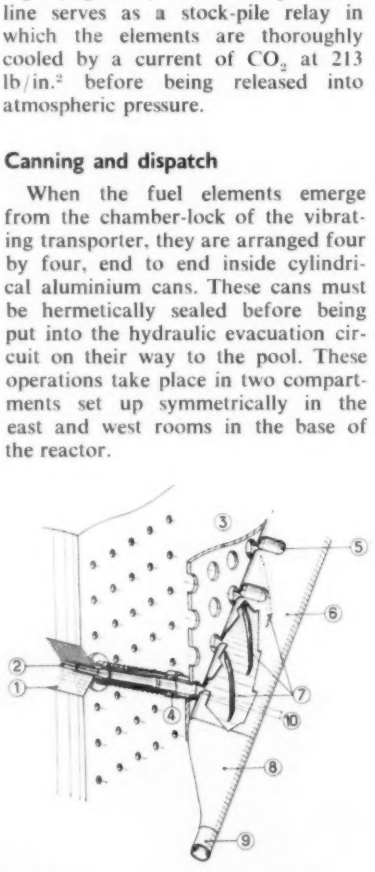
The conduits also transmit the thrust from the graphite due to thermal expansion and Wigner effect towards the bottom of the reactor.

The elements fall from channels of various heights and so have different velocities. To avoid severe shocks to their cans, their speed is regularized in the decelerating towers towards which the exit tubes converge in bundles of three. The elements are forced to fall through a square chute coiled inside the inner wall of the towers. Centrifugal force produces a frictional resistance which causes this velocity to tend quickly towards a limiting value close to 6·6 ft/s along an incline of 0·5. Though the inside of the deceleration towers is at nearly the same pressure as the gases in the shield, spiral conduits have been made sufficiently tight so that if a slug should be stopped, a cooling current of CO_2 can immediately be set up around the slug by adjusting the valve-gates in the exit tubes of the towers. Camshaft motors attached to the outer wall of the towers automatically vibrate the spiral conduits if the element does not arrive on time. But this emergency device has only been used on rare occasions. Biological protection from the unloading circuits at the exit of the reactor is ensured by concrete walls 4 ft 7 in. thick.

The deceleration towers are grounded in the reactor foundation. This is a hollowed-out structure where various hot rooms are installed. Each of the three towers is linked to a cylindrical enclosure under pressure containing a horizontal vibrating passage (Figure 4). This transportation line serves as a stock-pile relay in which the elements are thoroughly cooled by a current of CO_2 at 213 lb/in.^{2} before being released into atmospheric pressure.

Canning and dispatch

When the fuel elements emerge from the chamber-lock of the vibrating transporter, they are arranged four by four, end to end inside cylindrical aluminium cans. These cans must be hermetically sealed before being put into the hydraulic evacuation circuit on their way to the pool. These operations take place in two compartments set up symmetrically in the east and west rooms in the base of the reactor.



1 Graphite
2 Channel
3 Gas inlet-tank plate
4 Ball joint
5 Gas inlet aperture
6 Fuel element collector
7 Deflectors
8 Funnel
9 Evacuation duct
10 Slope angle

This diagram shows the deflector arrangement in the unloading collectors (Fig. 3)

When a filled cylinder reaches the last cooling position, it is taken up by a second mechanical arm which deposits it on the moving belt of the sealing machine. The ends of the aluminium tube are then crush-sealed.

At the last position along the transporting chain a third transfer arm takes over the sealed can, makes sure that it has not been deformed during sealing, then carries it up over the receiving apparatus of the hydraulic evacuation circuit and drops it. A rotating trough lines up the aluminium can in the transport tube where it is flushed away towards the cooling pond by means of a pressure pump.

Controls

All the machine control is completely automatic. A signal network makes it possible to gather all the data concerning the various machines and the position of the fuel elements and relay this information on to synoptic control-boards (Figure 5). This network is reinforced by a series of contacts that only give the go-ahead signal on any operation when all the conditions of security are fulfilled.

In case a machine should break down, the persons in charge of the control-panels can always stop the normal automatic cycles and replace them either with emergency automatic cycles or else with 'step-by-step' operation. Near the synoptic control-panels television screens transmit images of the machines at work in the 'hot rooms' down to the minutest detail. Microphones have also been installed near the unloading tubes and in the machine rooms to allow the control engineers to hear the fall of the elements and the functioning of the gates, presses and machines. Thus, despite the intervening distance the operators at the central control station have an impression of being actually in the presence of the machines, which facilitates their work and makes it more alive.

Experience acquired

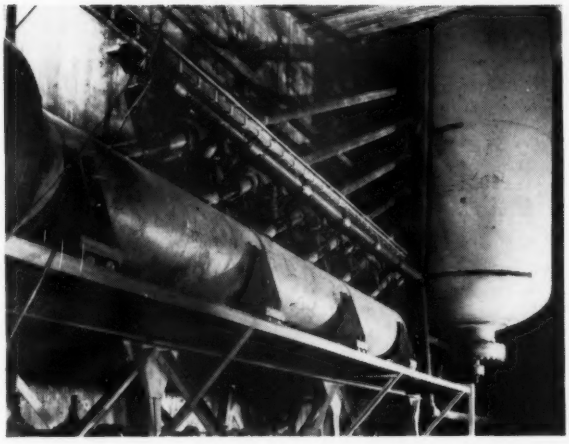
The loading and unloading installations have been in service since the beginning of 1959. Therefore it is now possible to draw some conclusions about the results of the system.

The first difficulty lies in the unloading method adopted which sends the irradiated elements through a complicated route made up of bends and multiple joints without the use of any manipulator. It is obviously an advantage to be able to utilize gravity as the only motor force and not to have any mechanism in the reactor that might be difficult to repair under pressure and in the neutron flux. But the engineering of this method required lengthy research and countless

experiments. Variations of the coefficient of friction of the magnesium canning against steel were studied systematically as a function of temperature, and also the influence of shocks and deformations of the fins on velocities obtained. The shape of the conduits and their couplings gave rise to laborious tests while the reactor was being built. Thus, for example, the deflectors had to be added under difficult assembly conditions inside the collector conduits at the exit of the live channels. After the reactor was working, occasional fuel elements became blocked because of deformations that could not be foreseen. Close collaboration on the part of the construction and maintenance services helped to smooth over these troubles by making a few changes in the vibrating transporters.

For greater security, gates were added that now constitute the inner section of the unloading tubes when they are open and can cut off the deceleration towers from the shield whenever necessary. These gates can be inspected through special openings when necessary. Other gates make it possible to isolate the vibrating transportation lines. Despite the absence of manholes that would give direct access to the channels of the core through the end, it is possible to reach any point along the route the elements follow either with a television 'mouse' camera or with emergency manipulators. The most difficult conduits to reach are the deceleration coils, but this disadvantage is not important inasmuch as the structure of these conduits is uniform. The rare element stoppages that have occurred in these coils have been caused by foreign bodies that accidentally got lodged in the conduits and abnormally increased the braking action. The camshaft motors installed easily shook the elements loose. The foreign bodies were then picked up in traps along the horizontal lines.

The operation of the sorting, canning and evacuation rooms has turned out to be very smooth. After the system had been working for a while, the minor modifications that seemed desirable were easily made. All the circuits that link up the control organs (hoists, presses, pneumatic and electric gates, electric contacts) are connected through special walls to the distributing boxes that house the relay systems and the selection and programming units necessary for control. Changes in the automatic stages were made without difficulty in the cabinets or on the panel-boards without touching the special installation impervious to the radiation in the hot-rooms. The cables



Connexions between deceleration tower and vibro-conveyor (Fig. 4)

of these installations were all manufactured by Pyrotenax technique.

A new approach

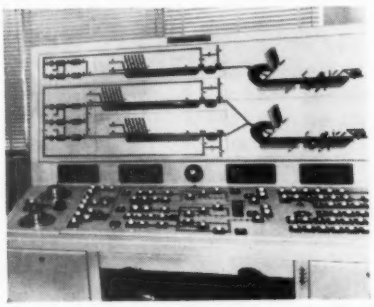
The general structure of the G2 and G3 reactors has two defects from the loading–unloading point of view: (*a*) direct access to the active channels is restricted to one end. This complicates the problem of designing the unloading mechanism because it reduces the possibility of emergency operation especially when the reactor is under pressure; (*b*) the plugs that stop up the channels on the loading end have a double disadvantage: they are long and they have to do duty as ramrods to pack in the fresh fuel. The loading machines must consequently be able to accommodate their full length as they are withdrawn from the reactor.

New research being done under the direction of the French Atomic Energy Commission is taking these facts into account in an effort to devise improved systems to load and unload while nuclear reactors are running.

These derivative systems of G2 and G3 will also have a host of other advantages as a result of this experimental research:

1. The working out of the G2 and G3 reactors has led to a clear separation of functions: loading through the front end, unloading at the rear, cooling and canning the used elements in the chambers beneath the reactor and command of the control rods and the vertical experimental channels from the upper part of the shield.

Synoptic control boards in the loading/unloading control room (Fig. 5)



2. The fuel elements undergo a minimum of strain in the live core; the horizontal position spreads out evenly what little strain there is.

3. The irradiation schedule is very flexible. Any number of elements can be unloaded and all fuel can be subjected to a uniform irradiation.

4. Since each channel remains filled even during the loading process, the movements of the elements do not appreciably disturb the neutron flux and therefore produce no reaction in the neighbouring channels such as is observed in vertical reactors when a channel is emptied.

5. For the same reason the gas flow varies only slightly during loading and thus it is not necessary to regulate this flow as the elements are being expelled.

6. Inside the core the elements always move in the same direction and only a short distance at each loading operation. Hence thermal variations are reduced to a minimum.

7. In case of a break in a fuel can, the defective element can be eliminated without upsetting the running of the reactor, unless of course the incident is serious enough to require a reduction of the neutron flux or even the draining off of the CO_2 in the pile. The method of unloading used makes it possible to localize the faulty element by observing the fission products given off as the train of elements proceeds through the channel.

As far as we know, the loading and unloading operations carried out in April 1959, when the G2 reactor was pushed up from 150 MWt to 205 MWt in a short space of time, set a world's high in the field of atomic reactors.

Processes

Techniques used by the CEA are nearer US than UK practice

ATOMIC ENERGY IN FRANCE

Uranium production at Le Bouchet

by H. HUET, Head of the Uranium Fabrication Department at Le Bouchet

THE SOLUTION obtained by dissolving concentrates in nitric acid at 36–40° Baumé is either sent immediately through special bed filters on vertical screens in a container, or, preferably, filtered by gravity, in large vertical reservoirs. After several days the clear filtrate is taken to a solvent extraction plant. The siliceous deposit, well stirred, is then easily filtered using a rotating filter, which gives a better yield than the filters mentioned above. The filtrate is adjusted to 1·5–2 N with nitric acid, and purified in vertical columns equipped with raschig rings and blown with compressed air. The solvent is a mixture of tributyl phosphate with 30–35% white spirit. Washing with 4 N nitric acid is carried out in the upper part of the extraction column. The solvent recovered at re-extraction is itself washed periodically with sodium carbonate and then reacidified with nitric acid.

The interfaces, maintained for extraction, and re-extraction in the upper part of the column, are kept at their normal level by using differential floats which automatically control the output at the base of the column by means of a pneumatic valve. Also, for extraction, a float at the 'enriched solvent' outlet regulates the incoming impure solution by density, that of the recovered solvent being constant.

Precipitation

The pure re-extracted solution is continuously neutralized by a solution of ammonia (at about 22 or 25° Baumé) between pH6 and pH8, in two calandrias, the valve assembly of the second calandria being controlled by a pH meter. It precipitates a mixture of the trioxide and hydrated ammonium diuranate, that can be left as desired to mature in a 'polydecanter' placed between the calandrias and the vacuum rotating filters.

The conditions of precipitation and filtration (pH, temperature, degree of agitation, time of maturation, depth of precipitate on the filter, degree of vacuum, etc.) depend on the product desired, either fluoride or oxide for sintering. In the former case the acidity is controlled to pH8 to avoid grain growth. The precipitate is collected and washed on a rotating filter and, by the use of compressed air, sent to a continuous drying furnace.

Drying and calcining the trioxide

The original conception of the reactor has enabled us to make considerable progress in the fabrication process, showing itself in a substantial fall in costs. Constructed by our engineers from their own plans, it is at the moment the subject of a patent claim, so only a few details can be given. It is a continuously working band furnace, consisting of two parts for drying and then calcining the product. In the course of this operation the product loses its ammonia and the major part of its water of crystallization (at 400°C the stable oxide is $UO_3 0{\cdot}5H_2O$) and comes out in compact granular form excellently suited for taking to the final reduction and fluorination stages.

Reduction and fluorination

We group these two operations together because at Le Bouchet they are now carried out in a single apparatus, using a new process which, with calcination, represents a recent innovation. Previously the reduction and fluorination processes were carried out separately, the first in a vertical cylindrical furnace of heat-resistant steel, the second in a monel furnace sectioned on account of the increase in size produced during the dioxide-HF reaction. For this reason we had to install a 'dioxide pelletizer' before introducing the oxide in the fluorination reactor. We were able to carry out 'pelletization' in the UO_3 stage, before reduction, using the American 'pelletizing' method, like that employed at Narbonne; but in the meantime we carried out tests on a pilot cascade reduction-fluorination plant and, as these were decisive from the start, we immediately modified the fluorination building —under construction on the basis of an annual production of 500 tons—to incorporate reduction-fluorination equipment identical to the pilot plant.

We are now able to give some technical details of this installation as patents have been obtained. Each unit, capable of producing 100 tons of uranium a year (250 working days), is shown diagrammatically in Fig. 1. It consists essentially of an electrically heated reduction furnace of which the cylindrical tube of heat resistant steel has a diameter of 200 mm and a fluorination furnace, also vertical, with a monel tube with a conical base. These two furnaces are not used like those previously employed

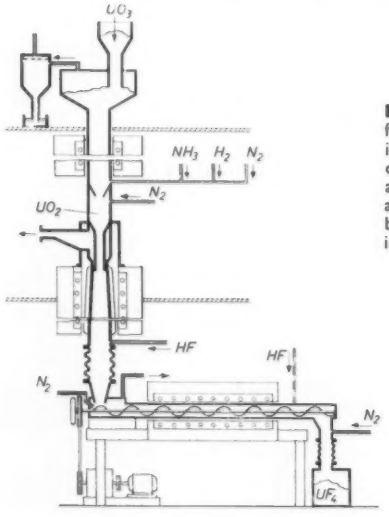


Fig. 1 The reactor for reducing uranium trioxide to dioxide is located above the fluorination reactor, and both use the 'moving bed' technique

in the separate operations of reduction and fluorination; they are placed one under the other with a device between them allowing the formation of a nitrogen film, which avoids a mixture of ammonia reducing the residual gases coming from the fluorination reactor. A differential manometer controls the amount of this intermediate nitrogen. The reduction can, therefore, be carried out at low temperatures, giving an extremely reactive dioxide.

At the outlet to the vertical fluorination reactor the product is very suitable for reduction by calcium but there is the risk that it still contains too much oxygen if reduction by magnesium to the metal is desired.

Nearby is a horizontal fluorination reactor, also electrically heated, which has a monel screw to stir the product and ensure the completion of the reaction and discharge of the fluoride. The fluoride thus obtained is 98% UF_4 and is suitable for reduction with magnesium.

The installation is completed by automatic loading and unloading devices for the solids, and a small steam-heated vaporizer for supplying the reactors with hydrofluoric acid, and condensers for the residual gases. Excess hydrofluoric acid (about 15% of the stoichiometric amount) is stopped by a double condenser, the first in monel or silver, cooled by water, the second in steel cooled to −22°C.

The vertical reduction and fluorination reactors use the 'moving bed' technique. This process has numerous advantages, among others the utilization of gaseous reactions, counter-current flow, absence of dust, and a minimum amount of abrasion; only a small amount of the product is in contact with the walls, thus limiting the pollution risk; other features are simplicity and ease of transportation, etc.

It is worth noting that the Canadians, in their works at Port Hope, have followed us in adopting a similar process but with separate reactors, and that their reduction reactor necessitates preliminary processing of the trioxide to pellet form. We think that the moving bed principle such as that now in operation at Le Bouchet shows up well in comparison with other techniques evolved, such as fluidization, which has a less general range; this also requires a rigorous granulization of the product, which has scarcely been needed till now at the reduction stage. It has been carried out in the USA, but for work involving the production of UF_6 and using very pure concentrates,

1. Base plate
2. Tube for exhausting and argon inlet
3. Bell
4. Steel crucible
5. Interior of furnace
6. Closing device
7. Firing device
8. Crucible of fritted fluorite
9. Lining of ram-packed fluorite
10. Side opening
11. Manometer

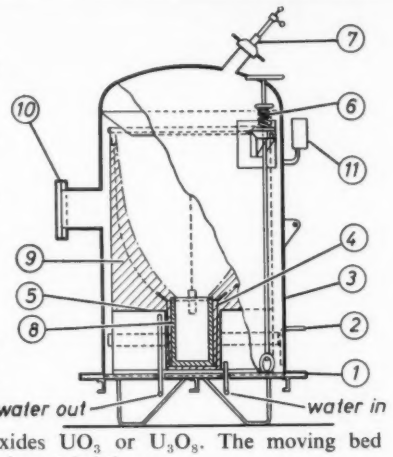


Fig. 2 Making 80-kg uranium ingots by reducing with calcium

in practice the oxides UO_3 or U_3O_8. The moving bed technique had also been tried there.

The processes used at Le Bouchet are not at all restrictive. The trioxide obtained in our drying-calcining plant can be used either in the reduction-fluorination reactor to give fluoride or in the separate reduction reactor, slightly modified, to give UO_2 suitable for sintering.

The continuous reduction reactor has a discharging screw about one metre long, surrounded by a water jacket. In this part reoxidation can be carried out to conserve the oxide. The conditions of reduction and reoxidation, and the temperatures used give an oxide which has a density of 10·6–10·7 after sintering. Similarly the fluoride obtained from the horizontal fluorination reactor is suitable for reduction by magnesium and also the production of the hexafluoride using fluorine. It is extremely well suited for reduction by calcium, a process which is being used in the industrial plants at both Le Bouchet and Narbonne.

Eighty-kilogram ingots are made in the apparatus shown diagrammatically in Fig. 2. The yield is 99%.

Very satisfactory trials have been carried out using magnesium reduction, giving a mean yield of 95%, with a process similar to that in use in the USA and Canada. We envisage extensions to the plant but it is necessary as a start to create in France a facility for producing magnesium of nuclear purity.

Materials

The changes in physical and mechanical properties after irradiation have now been investigated

ATOMIC ENERGY IN FRANCE

Beryllium oxide and its uses

by J. ELSTON, Metallurgy Department, CEA, Saclay

BERYLLIUM OXIDE has nuclear properties promising enough for its use as a moderator or reflector to be considered (*1*) (*2*). Its physical and metallurgical properties and methods of fabrication have been investigated (*3*) (*4*) (*5*), and its use would seem to be indicated particularly for high temperature power reactors. Shapes for nuclear applications can be made by sintering beryllium oxide powder prepared by calcination of the sulphate or the hydroxide. A method of sintering under pressure has been developed for the production of dense pieces of various shapes (*6*) (*7*) (*3*).

It is well known that at high temperatures steam causes volatilization (*8*) (*9*). The corrosion produced by a current of air saturated by water vapour at 25°C passing at 40 metres an hour over a specimen of the sintered material of high density (for example 3·0 g cm^{-3}) is negligible at 1100°C; the loss of weight observed under these conditions is less than 2×10^{-5} mg per hour per cm^2 of surface. Above this temperature the curve of Fig. 1 shows that the speed of volatilization in humid air is no longer negligible and seems to increase linearly from about 1150°C; at 1500°C the attack on the surface is severe. At 1200°C the corrosion is mainly intergranular (Fig. 2).

The results to be outlined were obtained from (a) non-irradiated specimens made by sintering under pressure and (b) identical specimens irradiated at a temperature below 100°C. The levels of irradiation are represented by the notation I, II and III (Table 1).

TABLE 1 *Irradiation flux employed*

	INTEGRATED FLUX OF THERMAL NEUTRONS n.cm^{-2}	INTEGRATED FLUX OF FAST NEUTRONS (> 1 MeV) n.cm^{-2}
Irradiation I	$5{\cdot}5 \times 10^{20}$—1×10^{21}	5×10^{19}—7×10^{19}
Irradiation II	2×10^{20}—4×10^{20}	$1{\cdot}2 \times 10^{19}$—$3{\cdot}5 \times 10^{19}$
Irradiation III	2×10^{21}—$3{\cdot}5 \times 10^{21}$	2×10^{20}—3×10^{20}

Crystal parameters The change in crystal parameters resulting from irradiation by fast neutrons is worked out on the diagrams of Debye and Scherrer obtained from marks cut in the specimens; the technique used has been perfected by P. Perio and E. Benignus (*4*). In the case of Irradiations I and III, Table 2 shows that the increases of the parameter c are about ten times more important than those observed on the a axes. Irradiation III caused the specimens to disintegrate. An examination of the powder, made by a recording goniometer with monochromatic X-rays (Cu, $K\alpha_1$, $K\alpha_2$), showed, in addition to the expansion of the lattice, an increase of the lines (002) (102), (103) etc. which corresponds to a disturbance of the lattice following the direction perpendicular to the plain of the base (002) (axis c). The expansion of the lattice entails an increase in the length of the specimens. This expansion depends on the dose received as well as on the density of the samples as shown in Table 3.

TABLE 2 *Change in crystal parameters*

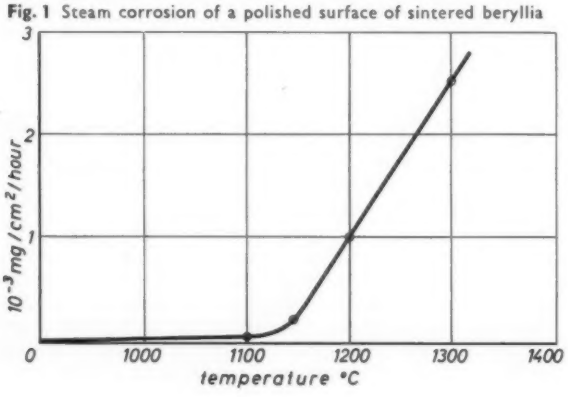
	$\Delta a/a$	$\Delta a(I)/\Delta a(II)$	$\Delta c/c$	$\Delta c(I)/\Delta c(II)$
Irradiation I	$+ 0{\cdot}36 \times 10^{-3}$	3·27	$+ 3{\cdot}1 \times 10^{-3}$	3·27
Irradiation II	$+ 0{\cdot}11 \times 10^{-3}$		$+ 0{\cdot}95 \times 10^{-3}$	

TABLE 3 *Change in length*

FLUX	DENSITY	$\Delta l/l$
I	2·70	$1{\cdot}1 \times 10^{-3}$
I	2·90	$1{\cdot}3 \times 10^{-3}$
I	3·00	$2{\cdot}5 \times 10^{-3}$
II	2·62	$0{\cdot}48 \times 10^{-3}$
II	2·74	$0{\cdot}57 \times 10^{-3}$
II	2·93	$0{\cdot}80 \times 10^{-3}$
II	3·00	$0{\cdot}96 \times 10^{-3}$

Thermal conductivity A peculiarity of BeO is its very high conductivity for a ceramic. The coefficient of thermal conductivity depends on the density, the values measured at 150°C for specimens of density 2·7–3·0 being between 0·3 and 0·45 cal/cm/sec/°C. At 1500°C it is of the order of 0·035 cgs for dense sintered specimens (*3*). Values of the coefficient measured between 100 and 250°C after radiation show an appreciable decrease as one can see from Table 4. The effect of heat treatment for some hours at 300°C on the irradiated specimens is practically negligible.

Fig. 1 Steam corrosion of a polished surface of sintered beryllia



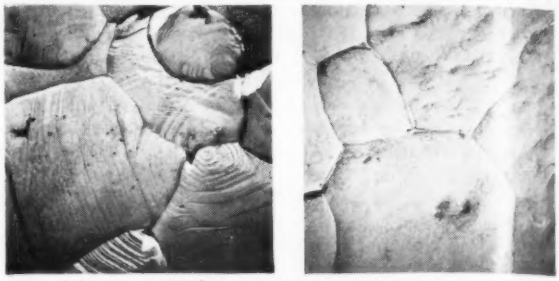


Fig. 2 (left) at 1500°C the whole crystal surface is attacked, note the symmetrical hexagonal marks (right) at 1200C only the grain boundaries are attacked (× 1700)

The effect at 500°C is a little more marked, but 800°C must be reached for the low density specimens from Flux II to recover their initial conductivity properties. A temperature of at least 300°C is necessary for the recovery of very dense specimens from Flux I.

TABLE 4 *Decrease in thermal conductivity measured at 140°C*

DENSITY	FLUX I	FLUX II
2·74 g cm^{-3}	69%	14%
3·00–2·99 g cm^{-3}	80%	32%

Modulus of elasticity The modulus of elasticity (E) is likewise very sensitive to irradiation. The value for E determined from an acoustic method (*11*) on specimens with a density between 2·6 and 3·0 varies between 2·48 and $3{\cdot}79 \times 10^6$ kg/cm^2. Table 5 shows the proportions in which the modulus decreases after Fluxes I and II. In the case of the specimen with density 2·9 the internal frictions become so important after Flux I that it was not possible to determine the modulus of elasticity by the method used. It again becomes possible to make a measurement on this specimen after annealing for two hours at 800°C; the value of E has then diminished by 64%. With the specimens from Flux I heat treatment at about 1300°C was necessary to recover (and exceed even slightly) the initial values of the modulus of elasticity.

TABLE 5 *Decrease in modulus of elasticity measured at 20°C*

DENSITY	FLUX I	FLUX II
2·62		19%
2·70	50%	
2·74		40%
2·90	64%	

Compressive strength This varies with density, and the dispersion in the results is rather important, especially in the case of sintered specimens of high density because of the presence of small traces of carbon. It was found that the compressive strength is little affected by Flux II. On the other hand the specimens of high density show a decrease of about 75% after Flux I. The resistance of the specimens to Flux III is practically nil, even in the case of relatively low densities.

TABLE 6 *Compressive strength of BeO sintered under pressure*

DENSITY	BREAKING STRESS AT 20°C
	tonnes cm^{-2}
$2{\cdot}75 \pm 0{\cdot}05$	7·5 to 16·2
$2{\cdot}85 \pm 0{\cdot}05$	11·7 to 17·5
$2{\cdot}95 \pm 0{\cdot}05$	7·8 to 20·3

Tensile strength The breaking stress at 20°C, lying between 600 and 860 kg/cm^2 for densities of the order of 2·65, can rise to nearly 1250 kg/cm^2 for very dense specimens. After Flux I the strength fell to 112 kg/cm^2 with densities between 2·6 and 2·7, i.e. a decrease of about 82%. This fall is of the order of 94% for densities from

2·84 to 2·88. Flux II has a sensible effect but it is difficult to calculate it in view of the dispersion observed with the non-irradiated test pieces. However the fall seems to be generally greater than 10%.

Summary

The change in the physical and mechanical properties of beryllium oxide under irradiation can be explained at least partially by the displacement of ions and the creation of faults in the crystal lattice (Wigner effect). Furthermore, one should not neglect the effects of the formation of gas in Be-9 under the action of fast neutrons from the (n,2n) and (n,α) reactions. Since after suitable heat treatment the crystal parameters of irradiated BeO recovered their initial values (*12*), the gas formed in the sintered specimen, if it is not evacuated collects at the grain boundaries (*13*). Now the presence of numerous pockets of gas dangerously lowers the mechanical resistance, especially in the case of dense specimens. Thus the evacuation of the gas should be assisted by an increase in porosity. As a matter of fact, the amount that is known about the diffusion of helium through these materials as a function of temperature is very meagre.

On the other hand, the deterioration of the mechanical characteristics after irradiation of type III, carried out at a temperature below 100°C, seems due mainly to the anisotropic deformation of the crystal lattice.

From the above considerations, a definite recommendation for the use of sintered beryllium oxide in power reactors cannot be given. Nevertheless, its use as a moderator might be justified, particularly for high temperature operation. There are indications that under these conditions behaviour under irradiation could be more satisfactory than has been indicated here, the present results only holding for irradiation at temperatures less than 100°C (*14*). The use of beryllium oxide at high temperatures, apart from irradiation effects, is not only limited by the risks of volatilization in the presence of steam above 1100°C. It must be noted that in addition the mechanical characteristics sensibly worsen with temperature. Thus, the compression strength determined at 500 and 1000°C in tests with different densities, is reduced to about a half and a quarter respectively of the values at 20°C.

It is probable that an optimum density exists for particular uses of beryllium oxide made by sintering. In that case it is possible that bars obtained by natural sintering give better results than those produced by sintering under pressure because of their greater homogeneity.

Acknowledgments

Thanks are due to MM. Salesse and Caillat for their interest in this work and MM. Frisby, Gewiss, and Morize who took part.

References

1. Koechlin, J. C., Martelly, J., Dugall, V. P., Geneva 8/P/359, 1955.
2. Sahai, K., Benoist, P., Horowitz, J., CEA/826, 1958.
3. Elston, J., Caillat, R., Geneva 15/P/1159, 1958.
4. Perio, P., Benignus, E., *Sch. Ph.*/430, 1957.
5. The Pechiney company, BF 1.130.111, Sept. 1956.
6. CEA, Pechiney, BF 1.129.566, Sept. 1956.
7. Caillat, R., Pointud, R., Geneva 8/P/345, 1955.
8. Grossweiner, L. I., Seifert, R. L., *J. Am. Chem. Soc.*, **74.** p 2701, 1952.
9. Elston, J., Caillat, R., Geneva 15/P/1147, 1958.
10. Livey, D. T., Murray, P., *J. Nuclear Energy*, **2.** p 202, 1956.
11. Mayer, G., Gigon, J., *J. de Phys. et le Radium*, **16.** p 704, 1955.
12. Elston, J., Gewiss, C., Labbe, C., *C.R.*, **249.** p 1635, Oct. 1959.
13. Frisby, H., Bisson, A., Caillat, R., *J. Nucl. Mat.* **1.** p 106, 1959.
14. Clarke, F. J. P., Williams, J., *C.R.*, **248.** p 672, Feb. 1959. AERE M/M 229.

Reactors

ATOMIC ENERGY IN FRANCE

Research and development of metallic and cermet fuels for reactors in use or envisaged is described

Developing new fuel elements

by J. L. BERNARD, M. ENGLANDER, M. GAUTHRON, and J. A. STOHR, Metallurgy Department, C.E.A., Saclay

THE INVESTIGATION and development of fuel elements in France have been carried out hitherto along two lines, (*a*) the development and production, by the most economical methods, of fuel elements, for graphite-moderated gas-cooled reactors, and (*b*) research work on the fuel elements likely to be used in other types of reactors such as: water-cooled reactors, whether under pressure or not; boiling water reactors; advanced gas-cooled reactors; sodium-cooled reactors.

Gas-cooled graphite-moderated reactors

The choice of natural uranium and CO_2 cooling necessitated limiting values for the uranium hot spot, the temperature of the cooling gas, and consequently of the can hot spot.

This latter limit has led to the adoption of magnesium alloys as canning material which have the advantage of low absorption cross-section and can also be formed by simple extrusion in a way suitable for heat exchange between the can and coolant.

Of these alloys, magnesium–zirconium (0·6% Zr) was selected because of its mechanical properties, its fine grain, the stability of the grain as a function of time and temperature (*1*) and its good corrosion resistance to CO_2 (*2*).

No diffusion bond can be effected between a magnesium alloy of this kind and uranium; the so-called 'mechanical linkage' can already used for the fuel element in the EL2 reactor (*3*) has been retained. This particularly economical type of canning, using either hydrostatic (*4*) or thermopneumatic (*5*) machines, inserts the can by shaping it, in square grooves machined in the surface of the uranium rod. These grooves prevent the 'ratchet' effect which is particularly pronounced in gas-cooled reactors.

Fig. 1 Tensile strength of U-Mo alloys compared with unalloyed uranium

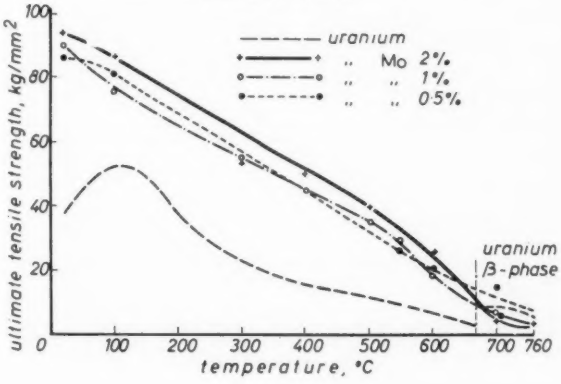


TABLE I *Mechanical properties of U-Mo alloys*

MATERIAL		ULTIMATE TENSILE STRENGTH kg/mm²	0·2% PROOF STRESS kg/mm²	ELONGATION %	REDUCTION IN AREA %
U (unalloyed)		43	20	5	9
UMo 0·5%	20°C	87·7	42	5·8	6
	500°C	35·1	25·9	15	33
UMo 1%	20°C	88·5	44·7	6·6	6·65
	500°C	34·6	21·2	18·2	48·7
UMo 2%	20°C	93·3	49	2·6	2·66
	500°C	38·7	36·6	9·6	25·35

The need for utilizing natural uranium only left a relatively restricted choice of methods for obtaining fuel whose rate of combustion would have to be some 3000 MWd/t. The possibilities were limited to:

A range of alloys as-cast, or heat-treated, with little opportunity for selecting additional alloying elements of a different nature or weight.

The forming of the uranium by rolling or extrusion, followed by heat-treatment for finer grain.

A combination of these two methods.

A rough-cast alloy was chosen for reasons of economy. This led to a search for an alloy which, by regulating melting and casting conditions, would enable a fuel to be used directly as melted. The best alloying element was molybdenum with additions of between 0·5 and 2% by weight (*6*); higher concentrations could not be used starting with natural uranium as basic material.

The resulting microstructures show that there are two phases: Uα and Uγ, whose ratio varies as a function of the molybdenum concentration in a progressively purified aggregate. These microstructures give the fuel mechanical properties much better than those of as-cast uranium (Figure 1, Table I).

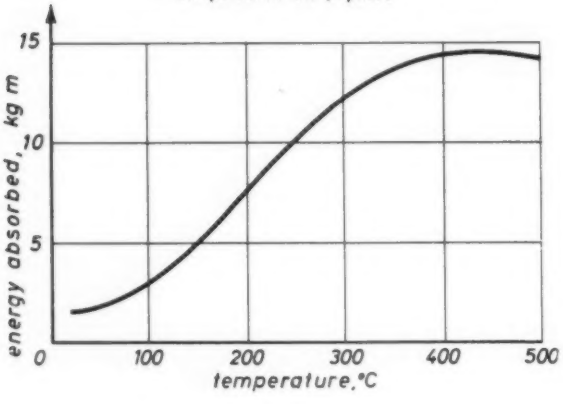
The results of irradiation of various test reactors show that none of the prototypes exhibit general dimensional instability.

The rate of combustion attained by the alloys (range 0·5 to 2% Mo) are between 1500 and 7000 MWd/ton for 'fuel' hot spots between 350 and 375°C.

Where certain considerations (chemical or neutron) exclude molybdenum alloys, an increase in dimensional stability has been obtained: by extrusion in the α-phase followed by tempering in the β-phase, annealing in the α-phase (*7*) (Figure 2 and 3). By adding 1000 ppm (*8*) of elements such as Cr, Si, Al (together or separately), the metal as-cast being subsequently heat-treated.

No troublesome dimensional changes have been observed but the combustion rates at present obtained are still too low to make it possible to say yet whether it will be feasible to use alloys of this kind in power reactors.

Fig. 2 Impact properties of uranium extruded in the α-phase tempered in the β-phase



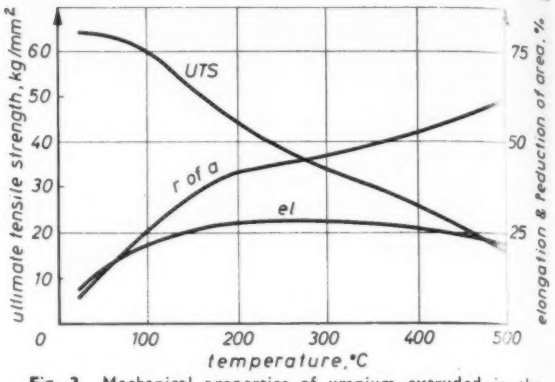


Fig. 3 Mechanical properties of uranium extruded in the α-phase tempered in the β-phase

The fuel elements have been made by private industry (Société Industrielle de Combustible Nucléaire) in close collaboration with the CEA. The manufacturing process comprises vacuum melting, chemical treatment, vacuum treatment of the fuel and can (*9, 3*).

The fuel element of reactor EDF1. (Figure 4), which is derived from the fuel element for reactors EL2 and G2, consists of a uranium alloy rod canned in an Mg-Zr tube with longitudinal fins.

A technical point of particular importance is that the welding of the fuel-can end plugs is completely automatic (*10*). The results have been excellent; the first set

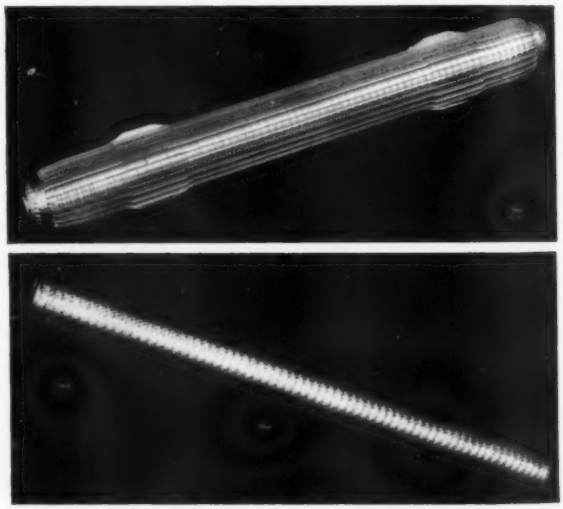


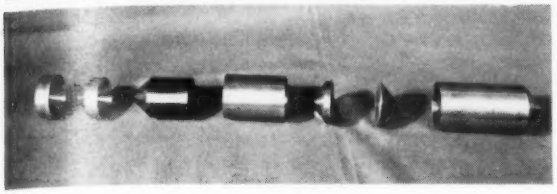
Fig. 4 (top) EDF 1 fuel element (bottom) proposed fuel element for EDF 2

of fuel elements for the G2 reactor at Marcoule has only shown a ratio of 1 leakage per 11,000 welds, assuming that all leaks are attributable to welds.

The possible performance of these types of fuel elements can be improved as a function of the geometry such as: tubular fuel (uranium hot point); can profile of herringbone pattern (*11*) giving better heat transfer characteristics.

These modifications are now under investigation with a view to producing the fuel elements for the EDF2 reactor (Figure 4).

Finally, the use of a Mg-Mn, Mg-Ce alloy for the end plugs of the cans (welding to the Mg-Zr can being effected without difficulty) or the banding of the plugs (*12*) may give certain facilities for fuel units piled one on top of the other.



Make-up of a co-extrusion billet (Fig. 5)

Other types of reactor

Reactors with non-pressurized water circulation Two types of fuel elements intended for EL3 have been experimented with and manufactured:

Metallic fuel (U-Mo to the extent of 1·5 to 10% by weight) canned in aluminium (*13*). This is the type of fuel used for the first five sets in the EL3 reactor.

The canning is of the 'mechanical link' type. Although the designs are of the same type as that used in the gas-cooled reactors, operation is entirely different (can temperature 120°C; 'flexible' can).

The combustion rate obtained with elements of this kind exceeds 7000 MWd/t without deformation.

Two points should be noted, (*a*) the can is closed at one end by extrusion (Centre de l'Aluminium, Gerzat) which saves one weld, and (*b*) electron bombardment for welding the end; this method reduces to zero the number of leaks, whereas the number was considerable when argon arc welding was used.

From the third batch onwards manufacture has been by private industry (CERCA) in close collaboration with the CEA.

UO_2 fuel, aluminium can The so-called 'snow crystal' can (*14*) is of the cluster type and is obtained directly by extrusion. An ingenious method of keying (*15*) ensures that the fuel elements will be properly fitted in the aluminium channel.

Pressurized water reactors Several types of fuel elements have been investigated.

Metallic fuel; zirconium or zirconium alloy can The fuel element is obtained by extruding together a U-Zr (2% Zr) alloy billet and a zirconium or zircaloy 2 can. Figure 5 shows the different parts forming a billet.

These parts are assembled, vacuum welded, placed in a protective jacket and simultaneously extruded (*16*).

Tubular elements, canned on the inside and outside, have been obtained by this method.

Ceramic fuel; stainless steel can The fuel element is of the cluster type with connexion by spacers or sheath.

Different alternatives have been investigated, particularly canning with a light gauge tube with walls between 0·05 and 0·1 mm thick: some samples are under investigation in reactors in France and Canada, encased with a thin cladding about 0·1 mm thick, obtained by extruding in hydrostatic or thermopneumatic machines.

Dispersed fuel; stainless steel cans Investigation of co-extrusion of UO_2 dispersed in a stainless steel matrix, canned with stainless steel, has made it possible to obtain rods and tubes with good characteristics (Fig. 6). The same type of element has been investigated by simultaneous rolling to obtain plates.

Metallic fuel; zircaloy can, obtained by simultaneous rolling An investigation is in hand for producing a plate element in which the fuel is a high-zirconium alloy (low uranium content) canned in zircaloy.

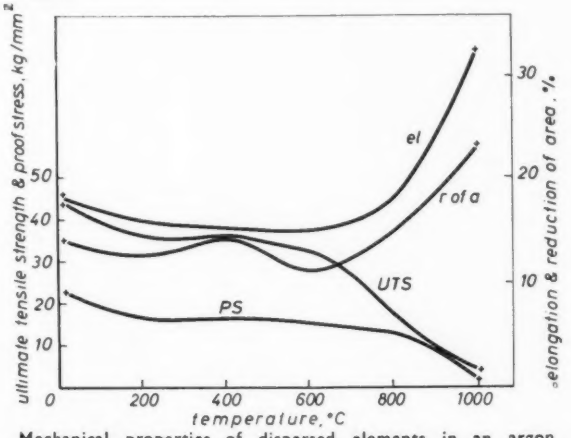
The method used is the frame system which has enabled us to obtain uranium–aluminium fuel elements canned with aluminium.

Advanced gas-cooled reactors ($\theta > 600$°C)

Fuel elements derived from water reactors Changing the canning material, and also the matrix material in the case of dispersed elements (replacing the 18-8 stainless steel with 80-20 nickel chrome) suggests the possibility of using these elements in gas-cooled reactors. The performances to be expected are substantially dependent on the coolant.

Ceramic fuel; beryllium can This type of cluster fuel element enables non-enriched fuel to be used.

Investigation is proceeding; it is impossible to foresee the future of these elements for economic and technical reasons.



Mechanical properties of dispersed elements in an argon atmosphere. Extrusion ratio 25, extrusion temperature 1200°C. The steel is INOX 302 B with 20% UO_2, grain size 100–150 μ (Fig. 6)

Boiling water reactors The fuels investigated for pressurized water reactors are all suitable for producing elements for boiling water reactors.

The external shape may be different but the extrusion method using hydrostatic or thermopneumatic pressure allows any shape to be obtained very easily.

Sodium-cooled reactors A metallic fuel element (U-Mo 10% alloy for the fertile element) canned with stainless steel, niobium or co-extruded niobium-stainless steel with intermediate sodium has been investigated and is being produced for the fast reactor Rapsodie.

References

1. Bernard, J. L., *et al.* Geneva Conference 1958, No. 15/P/1166. CEA Report 995
2. Caillat, R., and Darras, R. Geneva Conference 1958, No. 15/P/1146. CEA Report 983
3. Stohr, J. A., Englander, M., and Gauthron, M. Geneva Conference 1958, No. 15/P/1157. CEA Report 986
4. Ringot, C. Technical Symposium on Fuel Elements. Paris, 1957. CEA Report 782
5. Gauthron, M. Technical Symposium on Fuel Elements. Paris, 1957. CEA Report 783
6. Lehmann, J. (Mme). CEA Report 920
7. Sauve, Ch., to be published as a CEA report
   Englander, M., Laniesse, J. (Mme), and Meriel, P. *Acad. Sciences Report* 1959, **249**, Dec. 2576-78
8. Laniesse, J. (Mme) to be published as a CEA report
9. Gauthron, M., and Nadal, J. Congress on Reactor Materials, Stockholm, Oct. 1959
10. Stohr, J. A. Technical Symposium on Fuel Elements, Paris, 1957
    Briola, J. Geneva Conference 1958, No. 15/P/1161. CEA Report 990
11. Salesse, M., and Stohr, J. A. CEA Patent, No. PV 780,916 of December 5, 1958
12. Alfille, L., and Ropers, J. CEA Patent, No. PV 779,398 of November 18, 1958
13. Guibert, B., de Lasteyrie, B., and Doumerc, J. Congress on Reactor Materials, Stockholm, Oct. 1959
14. Salesse, M., and Stohr, J. A. CEA Patent No. PV 755,948 of January 15, 1958
15. Guibert, B. CEA Patent No. PV 810,559 of Nov. 18, 1959
16. Montagne, R. *et al.* CEA Report No. 1171
    Stohr, J. A. *Metaux-Corrosion-Industries* 1959, May, No. 405

ATOMIC ENERGY IN FRANCE

Electrostatic machines at Grenoble

New types of particle accelerators have been developed

FOR MANY YEARS the development of electrostatic generators for industrial use as well as for research purposes has been actively carried out in the laboratories of Grenoble University under the direction of Professor Noel Felici. The success of this project is, to some extent, indicated by the rapid growth of an industrial firm in Grenoble, SAMES, formed to exploit the commercial possibilities of the Felici machines.

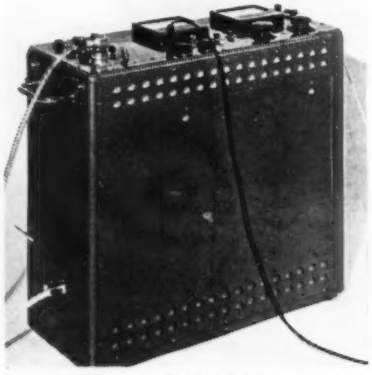
It was seen that SAMES electrostatic generators would form suitable power units for electrostatic particle accelerators; consequently an Accelerator Division was set up to manufacture complete accelerator installations. With the establishment of the Grenoble nuclear research centre this Division's activities increased and a number of SAMES accelerators were built for neutron bombardment studies and research in radiochemistry (*1*).

Felici electrostatic generators

The Felici machine (*2*) consists essentially of a cylindrical rotor of insulating material which rotates at high speed (3000 rev/min) inside a cylindrical semi-conducting stator. Electrical charges are sprayed on to the rotor by means of ionizer blades, raised to a higher potential and removed. There are no rubbing contacts, commutation taking place entirely by spray discharge. In order to achieve high power outputs, the generator is housed in a pressure vessel containing hydrogen at a pressure of 15 to 25 atmospheres. Commercial versions of the machine have power outputs of about 1 W/cm^2 of rotor surface and currents of about 0·17 mA per cm of rotor length are obtained. The efficiency of these machines is $> 90\%$ for voltages in excess of 100 kV and is much higher than that of the driving motor. These machines are extremely reliable and, normally, never have to be removed from the pressure vessel during their working life.

The generators are controlled by regulation and stabilization circuits and very high voltage stabilities can be obtained. In one version, the 'Samtron,' the output voltage is stable to 1 part in 10^5 at 100 kV. These high voltage stabilities are required for applications such as focusing supplies for particle accelerators and as a beam inflexion voltage source such as that used in the CERN proton synchrotron.

The voltage range of SAMES generators extends from 40 kV to 1·2 MV with currents from 30 μA to 50 mA. A 1·4 MV 4 mA machine has been made for the French Atomic Energy Commission. The generators can easily be connected in series or parallel and a small unit has been developed by SAMES giving 75 kV at 25 mA which can be coupled in parallel to give a total of 200 mA with a stability of $\pm$ 20 V. These machines are designed for use with ion sources, thermonuclear experiments or isotope separators.



The 'Samtron' 50 kV Felici generator has voltage stability 1 in 10^5

Generators available for use with accelerators

kV	CURRENT mA	STABILITY %
160	2·5	$\pm$ 1
250	7	$\pm\pm$ 1
600	4	$\pm\pm$ 1
600	4	$\pm$ 0·1

One of the most interesting applications of the Felici generators for acceleration applications is the supply of high voltage pulses of considerable power necessary for large accelerators. SAMES has built a unit giving 200 mA pulses at 600 kV and this pulsing technique has also been applied to their smaller machines. The voltage stability during the pulse can be made as high as 0·1%.

Trouble-free accelerators

The particle accelerators developed by SAMES are also of the electrostatic type. Although the basic design is fairly conventional much of the high voltage technique evolved during the development of the generators has obviously been incorporated in the accelerator designs. In particular, extensive use is made of Araldite moulding and potting.

The most important feature of these accelerators results from their use with a Felici generator. The generator is extremely small compared with rectifier units of comparable power and needs little attention, apart from routine maintenance of the electronic circuits. The accelerators are not pressurized and therefore all the components are completely accessible. With accelerators used for research it is important that the ion source should be easy of access so that modifications and gas changes can readily be made. With this requirement in mind, SAMES have separated the generator from the acelerator.

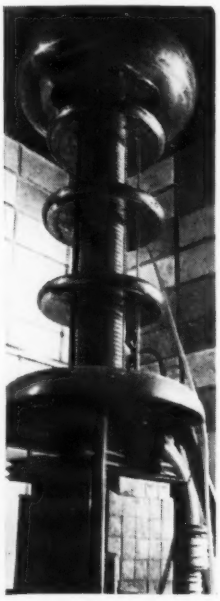
Various types of accelerator have been made for ion or electron acceleration and some versions can be switched for either ions or electrons.

Neutron sources

The most compact accelerator is the SAMES Type 'J' which is a double lens tube working at 150 kV with a maximum deuteron or proton beam current of 0·75 mA and beam diameter of 2 to 10 mm. The neutron output with the D/D reaction is 10^8 neutrons/s and 10^{10} neutrons/s with a tritium target. The accelerator can be pulsed, when ion currents of 1 mA during the pulse can be obtained. The pulse duration is normally 50 to 100 μs at a repetition frequency of 500 to 1500 c/s. Various configurations are possible; it has been used as a mobile neutron source for field use and can be fitted with a drift tube and used in conjunction with sub-critical assemblies.

A 250 kV accelerator which has been developed to give higher neutron

yields than the Type 'J' has an ion beam current of 1 mA. There is also a 600 kV accelerator which can be pulsed if required. This has a four lens tube, supplied by a 600 kV 4 mA



The SAMES 600 kV accelerator used in French universities and by the AEC gives high steady neutron rate

SAMES generator. When used as a steady source, the maximum ion beam current is 0·6 mA. This figure increases to 1 mA when the accelerator is pulsed. With the D/Be reaction, neutron rates of $2 \cdot 10^{10}$ neutrons/s are obtained.

It is an advantage to have neutron sources which can give high steady neutron rates, as well as pulsed neutron burst. Steady state measurements can be made on sub-critical assemblies or moderator materials, as well as the important transient measurements using neutron pulses.

Electrons for radiochemistry

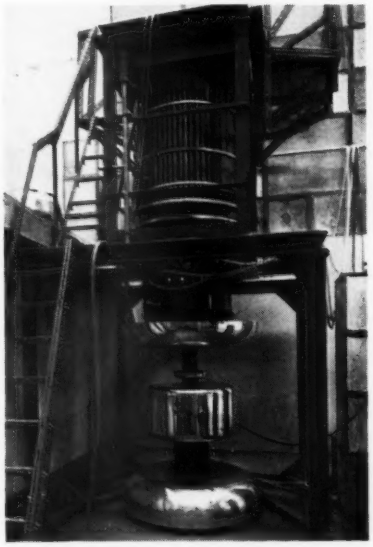
600 kV has proved to be a useful electron beam energy for industrial irradiation research and a number of 600 kV accelerators have been built for this purpose. Some of these machines are switchable for ions or electrons, having electron beam currents of 3 mA and X-ray dose rates of 500 to 1000 r/s are obtained a few centimetres from the target. These accelerators are being used for radiochemistry studies by the Atomic Energy Commission, the National Centre for Scientific Research and the Laboratory for Atomic Synthesis. Two are installed in the Grenoble Nuclear Research Centre one of which is being used by the French Petroleum Institute.

Sub-critical assembly 'Uranie'

The CEA laboratory at Saclay has designed a sub-critical assembly 'Uranie' which can be used in conjunction with a Type 'J' accelerator for experiments on the steady-state and transient behaviour of multiplying media. 'Uranie,' which is being made under licence by SAMES for use by French universities, comprises 1630 kg of natural uranium in 163 bars immersed in natural water.

Future trends

Most of the research effort on electrostatic generators is now being directed to producing very much higher powers. Professor Felici is at present working on new dielectric media for his machines and it is probable that far more powerful electron accelerators will be developed that can



Sub-critical assembly 'Uranie' uses a type 'J' 150 kV accelerator

be used in the rapidly growing irradiation chemistry field. Developments of electrostatic machines will be one of the subjects discussed at an International Colloquium that is being held by CNRS this year in Grenoble from September 27 to October 1.

References

1. *Nature*. March 28, 1959 **183** 858
2. *Direct Current*. Dec. 1959 192

PROGRESS IN INDUSTRY

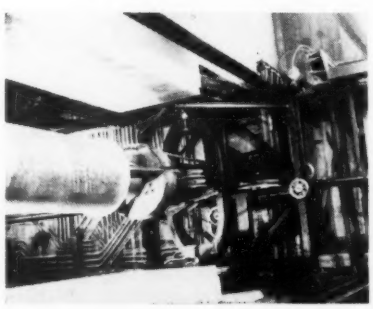
ATOMIC ENERGY IN FRANCE

The Marcoule plutonium extraction plant

The only industrial facility of its kind in Continental Europe

THE PROCESSING of the irradiated fuel elements from the French power reactors G1, G2 and G3 at Marcoule is carried out at a nearby plant which is operated by the Saint-Gobain Company. The plutonium extraction processes were developed from studies made by the Commissariat à l'Energie Atomique at their Fontenay-aux-Roses research centre. Construction of the plant commenced in June 1955 and by July 1958 it was ready to start operations.

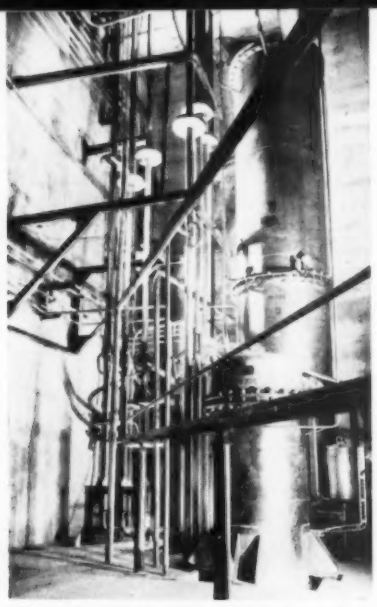
The production of plutonium in a perfectly pure state requires many intricate operations and these are



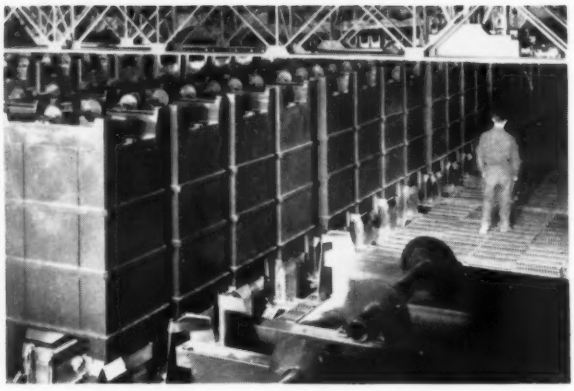
Remote-controlled grab for handling irradiated uranium

essentially chemical processing problems. Preliminary treatment is necessary, however, before processing can commence. The irradiated fuel elements are first taken to a pool for a period of cooling and decay (100 days or more), after which the uranium rods are taken from their cans. The rods are then transported by shielded conveyor belt to the factory where they are dissolved in boiling concentrated nitric acid. Escaping nitrous gases are recovered and returned to the special steel vessels as nitric acid.

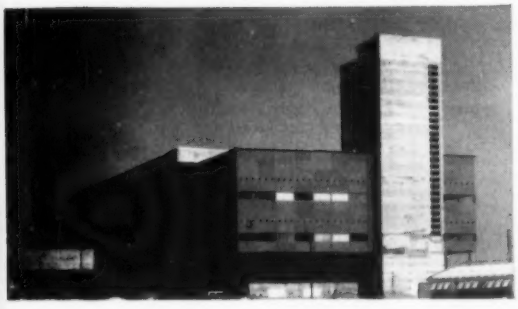
The solution obtained by this operation is made up of uranyl nitrate,



Uranium concentrate is produced in this evaporator after it has been diluted and treated with sodium carbonate



Air from the active and semi-active zones passes through 270 filters



General view of the plutonium extraction plant at Marcoule operated by the Saint-Gobain company

Sampling trip in the extraction room

plutonium and fission products and it has to undergo a series of selective and progressive extractions by the use of tributyl phosphate, to which is added a paraffin diluent (40% tributyl phosphate and 60% diluent), in three batteries of mixer-settler tanks. In the first battery, consisting of seven stages of extraction, one of dilution and six of nitric acid, the uranium and plutonium are separated from the fission products which remain in an aqueous phase. These are reduced in volume by evaporation in nitric acid and further treatment with formalin.

In the second battery, eight stages of re-extraction and two of tributyl phosphate dilution, the plutonium is extracted from the solvent in the form of a plutonium nitrate solution. Extraction is effected by using a reducing aqueous solution of uranium sulphate which reconverts the valency of uranium from 4 to 3. The third battery is used for uranium extraction.

The solution of plutonium nitrate which leaves the second battery is very much diluted and concentration is effected by precipitating the plutonium as hydroxide, using sodium uranate as the carrier. Uranium is introduced in the form of uranyl nitrate and the whole is adjusted to a suitable pH by nitric acid. The precipitate is dissolved in a very small volume of concentrated nitric acid. Zirconium and niobium impurities are removed by a 20% tributyl phosphate solvent while the iron, remaining uranium and thorium are eliminated by ion exchange resin in a nitric medium. Plutonium is then precipitated as plutonium oxalate which, by calcination at 150°C is transformed into plutonium oxide. Heating at 570°C in a current of fluorhydric acid and oxygen produces plutonium tetrafluoride which is finally subjected to a calciothermic operation in a high frequency furnace.

Material and equipment used at Marcoule

concrete	over 52,000 cu. yd	*lead*	3000 tons
stainless steel	2,000 tons	*ordinary steel piping*	over 60 miles
		stainless steel pipes	over 120 miles
electric cables	over 120 miles		
relays	10,000	*instruments*	1500

Zoning in the plant

Security and protection against radiation exposure is ensured by dividing the working areas into three carefully ventilated zones. The active zone is divided into separate workshops corresponding to the various process stages, and access to these is forbidden during operation and after shut-down until decontamination is complete. All the pipes and other apparatus containing radioactive solutions are located here. Control mechanisms and other machinery that require handling and maintenance are placed in an adjoining zone shielded from the active area by a protective layer of concrete. Joints and flanges are welded, pipes and other equipment subject to corrosion are made from thick stainless steel and pumps and fans have been abolished. Liquid movement is carried out by gravity or siphoning and a 40 ft tower holds the barometric columns placed upon the siphons to ensure that the liquids cannot escape at the moment of priming.

The semi-active area surrounds the active zone, from which it is separated by a thick protective layer of concrete. In addition to the control mechanisms mentioned above, it contains the measuring transmitters and handling apparatus for sampling. Access to this

zone is allowed only for short periods to specialist personnel undertaking sample handling, maintenance and other control operations.

The inactive zone is separated from the other two by a further protective concrete wall. The control panels for the various working processes are installed here; all mechanical movement being remotely controlled. Elsewhere control and supervision of operations in the active and semi-active zones is by television screen or special windows.

Each zone is pressurized in such a way that air can only leak towards a zone of least activity. Air passing through the active or semi-active zones is filtered by a system of 270 filters, replacement of which is entirely automatic.

PROGRESS IN INDUSTRY

ATOMIC ENERGY IN FRANCE

Fuel element fabrication at Annecy

SICN supplies the Marcoule and EDF reactors

ALL THE FUEL elements for the French power reactors (G1, G2, and G3 at Marcoule, EDF1 and EDF2 at Chinon) are made in one plant at Annecy which is operated by the Société Industrielle de Combustible Nucléaire, SICN. The first request from the Commissariat à l'Energie Atomique came early in 1954; SICN accepted the task and started building the first section for the G1 fuel elements. Thereafter progress was rapid:

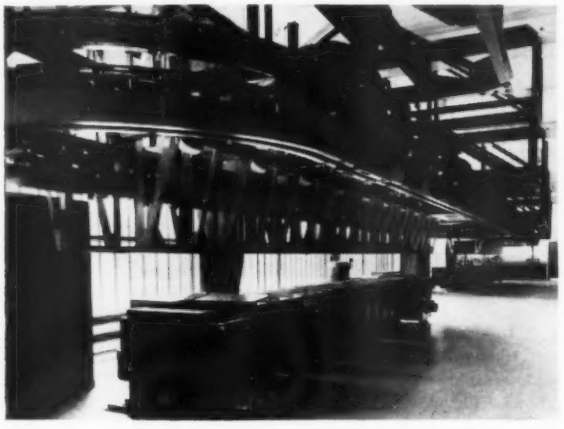
January 1956 Fuel elements for G1 criticality delivered

August 1956 to Sept. 1957 Factory extended for the production of G2 and G3 fuel elements

January 1958 First G2 fuel element produced

May 1958 to May 1959 Further equipment installed for the manufacture of EDF1 fuel elements

June 1959 onwards Extension to the factory for the production of EDF2 fuel



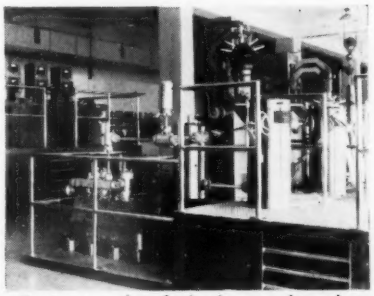
The canning undergoes a series of chemical treatments which are entirely automatic

Technical production

The problems that had to be faced were entirely new; the factory had to be organized to treat uranium by the hundreds of tons and produce fuel elements by the thousand, under conditions of perfect quality and regularity. The final methods adopted are basically similar to those used in the United Kingdom. The rod of natural uranium is first obtained by fusion and moulding in a vacuum, after which it is machine-tooled to give it its final form and proper dimensions. This is followed by cleaning and sand blasting and, after a last treatment of degasification under heat, carried out in high vacuum, the fuel element is ready for canning. The final canning operation brings the three fuel element constituents together: the uranium rod and the magnesium or magnesium-zirconium alloy can and plug. The plugs are first welded by argon-arc to the two ends of the rod, after which the uranium is inserted into the can. This is done either by subjecting the can to a hydraulic pressure of some 30,000 lb/in² or to a hot gas under pressure. The fuel element is finally polished, checked for tightness by helium detection with the use of a mass spectrometer, checked again and wrapped.

Inspection

Not the least important characteristic of this industry is the number of inspections that are made at every stage of the manufacture: checks on appearance, on dimensions, metallographic analyses of the uranium rods and the plug welding, checks on impurity rates in the uranium, chemical analyses of the processing baths, X-ray analyses of the finished fuel elements, and so on. The most important check is that made for the tightness of the element.



Equipment for fuel element insertion

Some thirty-five thousand fuel elements are required for the G2 reactor, consequently manufacture has to be done by mass production methods. Most of the operations therefore have been made entirely automatic in order to obtain maximum production and a strict identity of manufacturing conditions. Automatic-cycle argon-arc welding machines have been devised and the various series of chemical treatments, such as bath duration, stirring, etc, are carried out entirely automatically to ensure similarity of processing for each of the fuel elements.

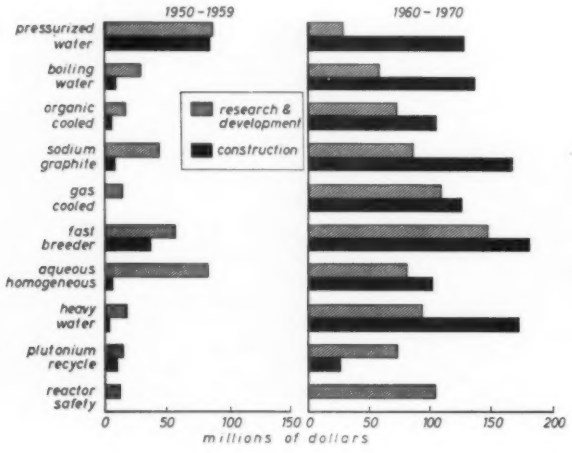
Clean conditions are necessary in the tooling room

A ten year nuclear power programme for the US

PART 1 *Summary of Technical and Economic Status as of 1959*
PART 2 *Economic potential and development programme*
PART 4 *Plans for development*

FOR SOME months the US Atomic Energy Commission has been analysing past government and industrial activities and, in the words of a report recently submitted to the US Congress, ' the Division of Reactor Development undertook the task of establishing a long-range programme for civilian power reactor development '. Generally the assessment was that units at present in service or under construction could not operate at maximum possible efficiency because the choice of conventional equipment and materials, such as pumps, grades of stainless steels, valves and piping had proved to be at fault.

In the US nearly seven hundred million dollars has been spent on civilian reactor development between 1950 and 1959. After carefully considering six broad classes of reactors, the AEC has indicated that if more than three times the finance is devoted to power units over the next ten years, an economical plant could be brought into operation. The proposed programme calls for research and development costing over £393 million ($M1100) and construction estimated at £400 million ($M1120) which would represent an excess of some £215 million ($M600) over the cost of erecting conventional plants of equivalent power. While constructive proposals have been made for each type of reactor reviewed, the Commission recommended that development should be specially accelerated in the fields of heavy water reactors, enriched gas-cooled reactors and organic-moderated reactors. The objectives of the AEC's programme are: **1.** To make nuclear power competitive in high energy cost areas of the United States within ten years. **2.** Assist friendly nations now having high energy costs to achieve competitive levels in about five years. **3.** Develop breeder reactors using thorium as well as uranium.



Over the next ten years the AEC, while planning to continue extensive research, propose to greatly increase the volume of power reactor construction

The AEC states that construction of a competitive pressurized water reactor plant could be started in 1963 or 1964. The application of the spectral shift, where heavy water is added to the light water coolant to extend fuel life, could possibly be made to a PWR. This would necessitate yet another prototype, in the 50–100 MWe range.

The best future for boiling water reactors is thought to be in the use of nuclear superheating and already several US companies are working on these lines (see *Atomic Power Proposals in America*, NUCLEAR POWER, December 1959. A 100 MWe prototype is recommended, and, if initiated in 1963, should lead to an economic 300 MWe unit by 1968–1969.

To make the organic-moderated reactor type worthwhile, the AEC, after criticizing the high costs for replacing decomposed coolants and the poor heat transfer characteristics, recommend short-term development to lengthen fuel life by using aluminium/aluminium oxide canning for uranium alloy fuel materials. For long-term development, the Commission states that its programme would be directed towards using plutonium recycling in OMR's. It is considered that concrete decisions for this type of reactor cannot be made before the middle 1960's.

Despite the AEC's admitted lack of complete understanding of the behaviour of liquid metal circuits, it reports that sodium-cooled reactors appear ' to have a high potential for achieving competitive power in large areas of the US in the late 1960's or early 1970's '. An added advantage of this type is the ability to achieve high conversion ratios or to breed. Advanced research should be directed, it is recommended, to improving fuel life, using uranium and thorium as blanket materials, and developing reliable and less expensive sodium components.

An alternative fast reactor in the form of the enriched fuel gas-cooled type has been included. After experience with the 22·3 MWe EGCR and the 40 MWe HTGR, both at present under construction, a 100 MWe prototype is proposed for the middle 1960's. In the meantime, investigations into fuels and fuel canning materials suitable for high burnup at fuel surface temperatures of 1700°F or more, and alternative coolants, are foreseen.

Some idea of the time basis for this proposed programme is seen from the estimated costs per annum, up to 1970, for the various types of fuel, canning and control materials. Work on uranium oxide will be tapered down after 1961 and is expected to be finished by 1969. Similarly research into uranium carbide fuelling and fuelled graphite will be cut down after 1963 and finished by the end of 1968. Canning material development will be maintained at an even level until 1966 and will be completed by 1970. Nuclear and reactor physics and general experimental problems will also be run down. To balance this general progressive reduction in research and development, more attention will be given year by year to research into nondestructive testing, waste studies and chemical reprocessing systems.

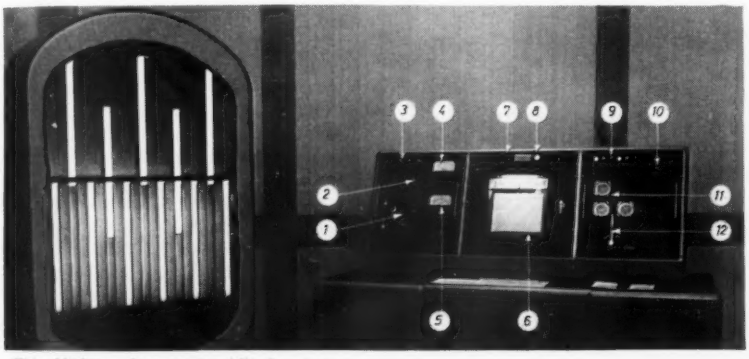
(Part 3 Technical Status Reports, summarised in Part 1, will be in seven or more volumes and scheduled for issue in April.)

STUDENTS' NOTEBOOK

GROUNDWORK—Reactors

What is the function of a reactor simulator?

The effective teaching of nuclear physics in technical colleges and universities requires facilities beyond the normal classroom techniques, particularly where lectures are concerned with reactor kinetics. In some instances, neutron sources, sub-critical assemblies or even small nuclear reactors are used, but these are beyond the means of most educational establishments. The approaching realization of the nuclear power programme of the CEGB brings with it the problem of training future reactor operators without the necessity of taking them to a nuclear power plant already in operation. The same problem exists with the training of selected crews for the future nuclear propelled ships, particularly *Savannah*.



This Vickers Armstrong Mk I reactor simulator and core model is operating under normal conditions. Shut-off rods are out and control rods half out. Fuel element condition is indicated by intensity of strip-light illumination

The problem is overcome by the use of reactor simulators, and the design of these varies according to the purpose they serve. The CEGB simulator, at Berkeley for instance, represents a graphite-moderated, gas-cooled, natural uranium reactor and the control desk carries all the plant controls and instruments of an actual reactor control desk, with the exception of the steam and water side of the boilers. For normal educational application however, such an installation would be both too expensive and unnecessary. Simpler simulators are available that can be used to supplement lectures on reactor kinetics and for initial training in reactor experimental programmes.

Simulators are based on analogue computer principles and, by means of electronic circuits, the equations relating to neutron flux, and other phenomena in a reactor are solved. Various configurations of fuel and moderator with an associated range of prompt neutron lifetimes may also be represented and the effectiveness of automatic control systems and calculations of change in reactivity due to fission product poisoning, temperature coefficient, etc. can all be simulated.

In the type illustrated, approach to criticality is achieved by setting the source strength (1) to give a shut-down power level of about 1 watt, the fuel selector to U-235 and prompt mean life control to $1{\cdot}5 \times 10^{-3}$ seconds. The trip warning lamps (7) are checked to ensure that the safety trips are not overridden. Shut-off rods are brought out (12) and the double mean time meter (4) gives a positive reading while the rods are moving. The control rods are withdrawn slowly allowing the power to become steady. Control rod positions are indicated on a circular dial (11) and condition by warning lights (9).

As criticality is reached and passed the rods are withdrawn more slowly and eventually the doubling time remains steady without further movement of the control rods. Reactor working is indicated by a red lamp (8) whilst shut down is achieved by pressing a button (10). Control and shut-off rods immediately drop under gravity. Power output is continuously registered by a visual single pen indicator recorder incorporating logarithmic and linear scales (6) and by a logarithmic power level meter (5).

Safety devices in the form of trips (2) provide for accidental criticality through adding too much fuel, excessive power level and other faults, and they operate in conjunction with warning lights (3).

BOOKLIST—Nuclear Engineering

Nuclear engineering. C. F. Bonilla (ed.) McGraw-Hill 1957. A review of reactor types and problems for engineers and physicists at graduate level.

Nuclear engineering handbook. H. Etherington (ed.) McGraw-Hill 1958. Basic data on reactor engineering, mathematics, formulae and calculation methods for reactor design. Summaries by specialists cover theory and practice.

The nuclear handbook. O. R. Frisch (ed.) Newnes 1958. In addition to basic data on nuclear science applications, short chapters cover materials, vacuum techniques, chemistry and electronics.

Principles of nuclear engineering. S. Glasstone. Van Nostrand 1956. Treatment is more theoretical than Stephenson or Murray.

Elements of nuclear reactory theory. S. Glasstone and M. C. Edlund. Van Nostrand 1952. Attempts to present the whole field in one volume, for physicists and engineers entering the industry.

Introduction to nuclear engineering. R. L. Murray. McMillan 1954. Basic information on theory, design, operation and materials for the engineer undergoing conventional training.

Introduction to nuclear engineering. R. Stephenson. McGraw-Hill 1954. Assumes knowledge of standard engineering technology and discusses only unique features.

Nuclear power engineering. H. C. Schwenk and R. H. Shannon. McGraw-Hill 1957. This is basically a simple approach with emphasis on reactor types, mainly American.

Thermal power from nuclear reactors. A. S. Thompson and O. E. Rodgers. Wiley 1956. Introduces fundamental engineering problems for engineers with no deep nuclear theory.

NEWSBRIEFS

• Oswald, used in early work on controlled thermonuclear reactions at AWRE, Aldermaston, will soon be on permanent view at the Science Museum.

• Griffin and George are awarding money prizes to science teachers for the best teaching ideas. The competition is being organized by the journal 'Teaching Science.'

• Since its creation in 1955, the National Council for Technological Awards has awarded 164 Diplomas in Technology, with 3750 students in the course of study.

UK COURSES

Harwell. Courses at the UKAEA Isotope School, Wantage Radiation Laboratories:

Isotopes, April 26–29. Course for directors and senior executives.

Advanced chemistry May 2–13

Medical course followed by three weeks visiting hospitals, May 16–June 2

Advanced physics and measurements, June 13–24

General isotopes, June 20–July 15

Autoradiography, July 18–22

Bradford Institute of Technology. Nuclear reactor technology, 6 weeks full time course, April 25–June 3. Fee: £30.

This survey of recent research into notched bar and other physical properties completes the review begun last month

Radiation damage in iron and steel-2

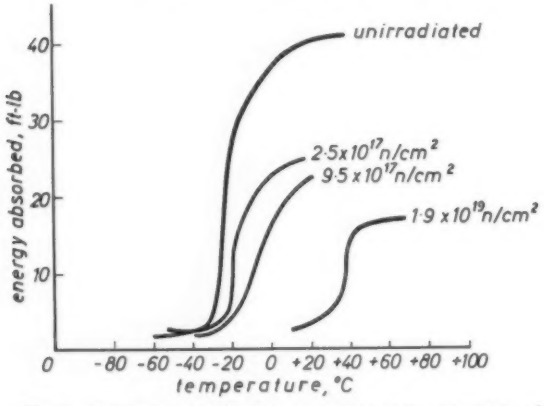
by D. R. HARRIES, B.Sc., Ph.D.
Metallurgy Division, AERE, Harwell

All the results described in both articles, except the creep tests which were conducted 'in pile,' were obtained by testing 'out-of-pile' after completion of irradiation.

Notched-bar properties

Ferritic steels The notched-bar properties of ferritic steels are even more markedly affected by neutron irradiation than the tensile properties. The effects on a plain carbon steel are shown in Figure 5. In addition to the raising of the ductile-brittle transition temperature, the energy absorbed values in the ductile-portions of the curves are considerably lowered by irradiation.

From the increase in tensile yield stress produced by



Effects of neutron irradiation on the impact properties of an En2 irradiated at 50–100°C (4) (Fig. 5)

irradiation, Cottrell (*16*) has derived a semi-empirical relation between the increase in transition temperature and the integrated neutron dose:

$$\triangle T = 17{\cdot}5\phi^{\frac{1}{2}}$$

where ϕ is the integrated neutron dose in units of 10^{18} thermal n/cm² under conditions where the ratio of thermal to fast neutron flux is about 10:1.

This relation was derived for an En2 steel with a ferrite grain size of 5000 gr/mm² irradiated at 100°C (max.). With a ferrite grain size of 20,000 gr/mm² the constant in this equation reduces to 13·6 showing that a fine-grained steel is more resistant to radiation damage than a coarse-grained steel (*17*). A dose of 1×10^{18} n/cm² produced no change in the transition curve of specimens with a ferrite grain size of 20,000 gr/mm². For the 5000 gr/mm² specimens, small doses ($2{\cdot}5 \times 10^{17}$ and 1×10^{18} n/cm²) caused a marked reduction in the energy absorbed in the ductile region of the curve and a small increase in transition temperature (*18*).

Using the $\triangle T = 17{\cdot}5\phi^{\frac{1}{2}}$ relationship, the increases in transition temperatures for various steels have been estimated and these are compared with experimental values in Table VI.

The predicted and observed increases in transition temperature are broadly in agreement although some of the results for the En2 steel do not occur in the correct sequence. Also, the estimated increases in transition temperatures for the low alloy and mild steels irradiated at 50°C are greater than the observed values. Conflicting evidence has been presented by Wilson and Sisman (*20*) on the relationship between the increase in transition temperature and the integrated neutron dose and their results are given in Table VII.

The changes in impact transition temperatures (10 ft-lb

TABLE VI *Comparison of experimental and estimated* $\triangle T$ *using the* $\triangle T = 17{\cdot}5\,\phi^{\frac{1}{2}}$ *relationship (19)*

STEEL	IRRADIATION TEMPERATURE, °C	DOSE, $\times 10^{18}$ n/cm²	ESTIMATED $\triangle T$, °C	OBSERVED $\triangle T$, °C
En2	100 max.	0·25	11	5 to 10
	" "	0·95	17	10 to 25
	" "	1·9	21	5 to 10
	" "	15	43	30 to 35
	" "	19	47	50 to 65
	" "	38	59	60 to 65
	" "	57	67	70 to 75
	" "	93	79	55 to 75
Low alloy	50	40	60	35
0·42% Cr; 0·26% Mo;	130	40	60	66
0·15% C; 1·19% Mn;	50	76	74	73
0·19% Si	130	76	74	74
Mild steel	50	26	52	29
0·13% C; 0·12% Si;	130	26	52	48
1·06% Mn				

TABLE VII *Effects of neutron irradiation at 80°C on the Charpy V-notch impact properties of steels (20)*

STEEL	INTEGRATED NEUTRON DOSE, n/cm² (> 1 MeV)	TRANSITION TEMPERATURE, MID-RANGE ENERGY VALUES °C*	MAXIMUM (DUCTILE) ENERGY*, ft-lb
ASTM A 212B (1)	—	−40	38
Normalized	1×10^{18}	−25	36
from 925°C	5×10^{18}	15	33
	7×10^{18}	25	30
	$1{\cdot}2 \times 10^{19}$	90	24
ASTM A285 A (2)	—	20	81
Normalized	1×10^{18}	45	73
from 925°C	4×10^{18}	60	76
	5×10^{18}	80	—
	7×10^{18}	105	64
	$1{\cdot}2 \times 10^{19}$	140	57
ASTM A301 B. (3)	—	25	60
	1×10^{18}	40	60
	4×10^{18}	50	56
	7×10^{18}	105	50
	$1{\cdot}2 \times 10^{19}$	155	43
ASTM A-200-55T	—	−30	200
Grade T-22 (4)	1×10^{19}	50	140
	$1{\cdot}7 \times 10^{19}$	70	130
Iron-carbon alloy (5)	—	45	200
Air cooled from 900°C	7×10^{18}	75	205
Iron-carbon alloy (5)	—	85	200
Air cooled from 1095°C	7×10^{18}	110	200

* These values are only approximate as they have been estimated from published curves..

(1) 0·2% C; 0·82% Mn; 0·22% Si. $\frac{5}{8}$-in. thick plate.

(2) 0·11% C; 0·32% Mn; $\frac{1}{2}$-in. thick plate.

(3) 0·11% C; 0·36% Mn; 0·22% Si; 0·98% Cr; 0·47% Mo. $\frac{1}{4}$-in. thick plate.

(4) 0·10% C; 0·45% Mn; 0·031% Si; 2·18% Cr; 1·00% Mo. 6 in. o.d., 0·5-in. wall thickness tube.

(5) 0·18% C; 0·002% Mn; 0·03% Si; 0·0039% O; 0·0003% H; 0·0001% N; < 0·003% P; 0·003% S; other metals ≤ 0·01%. $\frac{1}{4}$ by $3\frac{1}{4}$ in. bar.

level) as a function of integrated neutron flux (> 1 MeV) for all steels except the high purity iron-carbon alloy fall within a relatively narrow band. Above about 1×10^{18} n/cm² (> 1 MeV) the increases in transition temperature are a linear function of the integrated neutron dose. A similar relationship was obtained for the reduction in energy absorption above the transition temperature as a function of neutron dose.

The high-purity iron-carbon alloy shows lesser changes in transition temperature than the commercial steels exposed to the same dose. There is only a relatively small increase in transition temperature and no observable reduction in the ductile energy values. It appears, therefore, that metal purity in addition to the grain size has a considerable effect on the susceptibility to radiation change.

It has been reported that irradiation to a given dose at 130°C produces more damage as measured by the increase in ductile-brittle transition temperature than at 50°C (*21*). This effect was observed in a low-alloy steel and an aluminium-killed mild steel; however, a silicon-killed plain carbon steel showed similar increases in transition temperature when irradiated to the same dose at 50°, 85°, and 130°C respectively (*21*). These results suggest that the temperature dependence of radiation damage may be a function of the amount of carbide and nitride formers in the steel.

The effects of irradiation on the notched-bar properties of steels after irradiation at higher temperatures have been reported by Wilson and Berggren (*22*). Insufficient specimens were irradiated at each temperature to obtain complete transition curves but the results were analysed such that the temperature and flux dependence of the transition temperature shift could be estimated. The results for an ASTM A-212 Grade B carbon-silicon steel plate and carbon steel weld (E-7016 rod) are given in Table VIII.

The transition temperature shift is extremely sensitive to small changes in irradiation temperature in the range 260° to 315°C. It appears from the results in Table VIII that a temperature in excess of 315°C is required to anneal out the damage during irradiation.

Much of the effort on irradiation—brittle fracture studies at Harwell is being devoted to investigations of the effects of neutron irradiation on the notched-bar properties of weldable steels suitable for reactor pressure vessels (*23*).

Charpy V-notch specimens were machined from the parent plate and weld metal and specimens were cut with their lengths in the principal direction of rolling and notched in a face perpendicular to the surface of the plate. The ductile-brittle transition temperatures based on 50% fibrous fracture appearance before and after irradiation at 50°, 130°, 290°, and 325°C are given in Table IX. The mild steel has a much lower transition temperature (− 75°C) than the low alloy steel (7°C) in the unirradiated condition because of its finer grain size.

Significant increases in the ductile-brittle transition temperatures are produced by irradiation; the extent of the changes are governed by the temperature, integrated neutron dose and type of steel. In general, the weld metals show greater increases in transition temperature than the parent metal specimens for a given irradiation condition.

The magnitudes of the increases in transition temperatures are generally greater after irradiation to a given dose at 130°C than at 50°C. Irradiation at 325°C produces little change in the transition temperature of the low-alloy steel parent plate specimens and it appears that the damage is completely annealed during irradiation at this temperature. However, irradiation of the low-alloy steel weld metal and the mild steel parent plate and weld metal at this temperature causes marked changes in transition temperatures and a higher irradiation temperature would be required to anneal out the damage. Again, marked in-

TABLE VIII *Effect of irradiation temperature on the subsize Izod impact transition temperatures of a welded steel plate (22)*

STEEL	IRRADIATION TEMPERATURE, °C	INTEGRATED NEUTRON DOSE, n/cm² (> 1 MeV)	2 ft-lb TRANSITION TEMPERATURE, °C	INCREASE IN TRANSITION TEMPERATURE, °C
ASTM A212	—	—	−20	—
Grade B	80	2×10^{19}	103	123
carbon-silicon	260	2×10^{19}	95	115
steel	280	2×10^{19}	50	70
4-in. thick	295	2×10^{19}	24	44
plate. Hot	305	2×10^{19}	8	28
rolled	80	5×10^{19}	110	130
	295	5×10^{19}	66	86
	305	5×10^{19}	53	73
	315	5×10^{19}	18	38
Weld metal	—	—	−57	—
E-7016 rod	80	6×10^{19}	100	157
4-in. thick	260	6×10^{19}	90	147
multipass weld.	295	6×10^{19}	−10	47
Stress relieved	305	6×10^{19}	−50	7
	80	1×10^{20}	112	169
	295	1×10^{20}	−42	99
	305	1×10^{20}	−2	55
	315	1×10^{20}	−38	19

TABLE IX *Effects of neutron irradiation on the ductile-brittle transition temperatures of welded steel plates (21) (25) (26)*

STEEL	PLATE LEVEL	INTEGRATED NEUTRON DOSE, (5) THERMAL n/cm²	IRRADIATION TEMPERATURE °C	DUCTILE-BRITTLE TRANSITION TEMPERATURE °C	
				unirradiated	*irradiated*
Low alloy (1) steel 4⅝-in. thick plate Normalized from 950°C, welded and stress relieved at 675°C ASTM grain size 7–8 — Parent plate	¼ Depth	4×10^{18}	50	7	40
		4×10^{19}	130	7	65
		$7{\cdot}6 \times 10^{19}$	50	7	72
		$7{\cdot}6 \times 10^{19}$	130	7	70
		4×10^{19}	325	7	0
		$1{\cdot}14 \times 10^{20}$	290	7	35
Weld metal (3)	All levels	4×10^{18}	50	−18	58
		4×10^{19}	130	−18	75
		$7{\cdot}6 \times 10^{19}$	50	−18	100
		$7{\cdot}6 \times 10^{19}$	130	−18	105
		4×10^{19}	325	−18	0
		$1{\cdot}14 \times 10^{20}$	290	−18	27
Mild steel (2) 2-in. thick plate AL fine grain practice. Normalized from 920°C, welded and stress-relieved at 630°C for 4¼ hours. ASTM grain size 8–9 — Parent plate	Surface	$2{\cdot}7 \times 10^{18}$	50	−75	−42
		$2{\cdot}7 \times 10^{19}$	130	−75	−28
		$8{\cdot}5 \times 10^{19}$	50	−75	0
		$8{\cdot}5 \times 10^{19}$	130	−75	28
		4×10^{19}	325	−75	−30
		$1{\cdot}14 \times 10^{20}$	290	−75	−35
Weld metal (4)	Centre	$2{\cdot}7 \times 10^{18}$	50	−42	− 7
		$2{\cdot}7 \times 10^{19}$	130	−42	+ 2
		$6{\cdot}4 \times 10^{19}$	50	−42	40
		$6{\cdot}4 \times 10^{19}$	130	−42	55
		4×10^{19}	325	−42	10
		$1{\cdot}14 \times 10^{20}$	290	−42	20

(1) 0·15% C; 0·19% Si; 1·19% Mn; 0·42% Cr; 0·10% Ni; 0·15% Cu; 0·26% Mo; 0·06% V.
(2) 0·13% C; 0·12% Si; 1·06% Mn; 0·07% Cr; 0·07% Ni; 0·05% Cu; 0·05% Mo; 0·03% V.
(3) 0·12% C; 0·34% Si; 0·72% Mn; 0·16% Cr; 0·16% Ni; 0·16% Cu; 0·21% Mo; <0·03% V.
(4) 0·05% C; 0·14% Si; 0·47% Mn; 0·05% Cr; 0·11% Ni; <0·05% Mo.
(5) Ratios of thermal to sulphur neutron flux were about 6·5 (corresponding to irradiation temperatures of 50° and 130°C) and 17 (corresponding to irradiation temperatures of 325° and 290°C) in the irradiation facilities used.

creases in transition temperatures are produced after irradiation at 290°C. Assuming that most of the radiation damage in steels is produced by neutrons with energies in the MeV range, then, it appears that some annealing of the damage must be occurring during irradiation of the parent plate specimens of both steels at this temperature. This is because the transition temperature increases are less than after smaller integrated (sulphur) neutron doses at 50° and 130°C Hunter and Alger (*24*) have irradiated Charpy V-notch impact specimens of ASTM A 302 B and HY-65 high-strength pressure vessel steels, and weld metal deposited with types E 9016 and E 10016 electrodes at 200°, 285°, and 345°C to integrated fast fluxes. Their results are similar to those obtained from the Harwell studies.

TABLE X *Effect of irradiation and annealing on the yield stress of high-purity iron (8)*

	YIELD STRESS, lb/in²
Unirradiated	15,900
Irradiated 27·7 days at 80°C	22,100
Irradiated 27·7 days at 80°C and annealed 14 days at 300°C	18,200
Irradiated 27·7 days at 300°C	20,600

Austenitic steels The limited data of Wilson and Berggren (*11*) and Leeser (*27*) show that austenitic steels are not embrittled after irradiations of 10^{19} and 10^{20} n/cm² (> 1 MeV).

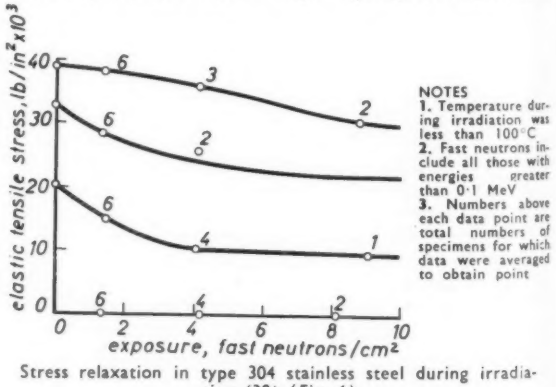
Creep

The creep behaviour of steels under neutron irradiation is not well defined. The very limited information available (*28*) (*29*) suggests that irradiation has only a slight effect on the creep rate of austenitic steels.

Joseph (*30*) has recently reported that neutron irradiation causes stress relaxation to occur in type 304 austenitic steel irradiated to doses of up to 9×10^{20} n/cm² (> 0·1 MeV) at 100°C (max.). The elastic stresses in the specimens, which were stressed in uni-axial tension by a fixed deformation to 20,000 to 39,000 lb/in² before the test, decreased 1000 to 10,000 lb/in² during irradiation as shown in Figure 6. No stress relaxation occurred in unirradiated control specimens that were heated to the same temperature as the irradiated specimens.

Fatigue

The effect of a neutron dose of 10^{19} n/cm² (>1 MeV) at 20–60°C on the fatigue strength of normalized boiler steel has been investigated by Leeser (*27*). In the unnotched condition, the endurance limit (10^7 cycles) decreased from an initial value of 48,000 lb/in² to 42,000 lb/in² for irradiated material. In the notched condition, the endurance limit increased from 28,000 lb/in² to 35,000 lb/in² after irradiation, the ratio of endurance limits, unnotched to notched, decreasing from 1·7 to 1·2 on irradiation. Leeser also observed that irradiation under the same conditions as



Stress relaxation in type 304 stainless steel during irradiation (30) (Fig. 6)

above had little or no effect on the fatigue properties of type 304 austenitic stainless steel in either the notched or unnotched conditions.

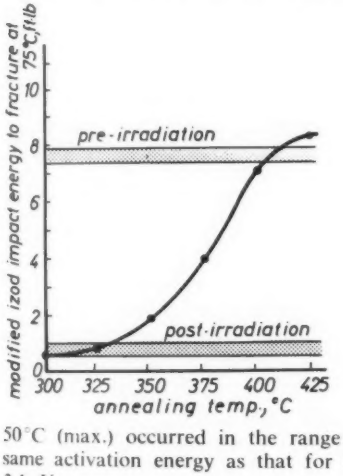
Magnetic susceptibility

Several authors (*31*) (*32*) (*33*) have observed the transformation of austenite to ferrite by neutron irradiation in type 347 austenitic steels by measuring the ferromagnetic saturation induction. Bailey and Silliman (*33*) found increases of 4 and 7 parts per thousand ferrites after irradiation to integrated doses of $6{\cdot}2 \times 10^{20}$ and 2×10^{21} n/cm² respectively. However, the amount of austenite transformed to ferrite is not sufficiently large to affect either the density or corrosion resistance of the steels.

Annealing of radiation damage

The fast neutron atom displacement damage (vacancies and interstitials) being a disordering of the lattice can be irradicated by heating when the atoms re-arrange themselves. Thus, heating an irradiated metal to a temperature sufficient for self-diffusion to occur will recover many of the properties.

Kunz and Holden (*10*) found that annealing of the radiation damage, as measured by the increase of yield stress, in pure iron single crystals irradiated to 10^{18} n/cm² at



Recovery of impact energy due to annealing ASTM A212B steel irradiated to an integrated neutron dose of 2×10^{20} n/cm² (< 1 MeV) (34) (Fig. 7)

50°C (max.) occurred in the range 225–300°C with the same activation energy as that for self-diffusion, namely 3·1 eV.

Figure 7 shows the mode of recovery of the notch-impact properties of an ASTM A212 B steel irradiated at 100°C to an integrated neutron flux of 2×10^{20} n/cm² (> 1 MeV) (*34*). The irradiated specimens were annealed at temperatures in the range 300–450°C for 1 h and then tested at a temperature at which the unirradiated specimens were ductile and the irradiated specimens were brittle. The impact energy begins to recover after 1 h at 350°C and the process is complete after 1 h at 425°C. Pravdyuk *et al.* (*13*) also reported that recovery of a considerable portion of the changes in tensile properties of a low-alloy steel irradiated to 1×10^{19} n/cm² (> 1 MeV) at an unspecified temperature occurs on heating for 2 h at temperatures in the range 250–400°C.

Post-irradiation annealing experiments indicate that radiation damage in type 347 austenitic steel irradiated to $1{\cdot}2 \times 10^{20}$ n/cm² (fast) begins to anneal out between 200° and 400°C and that 1 day at 600°C produces almost complete recovery (*35*).

Irradiation at temperatures above 300°C causes less damage than irradiation at lower temperatures. However, Bruch and McHugh (*8*) have shown that irradiation effects at elevated temperatures cannot be simulated by annealing at the elevated temperature after irradiation at a lower temperature. Their results on high-purity iron are given in Table X. A larger change in yield stress is produced by irradiation at 300°C than by annealing at 300°C after irradiation at 80°C.

Conclusions

It is now well established that irradiation of steels, in common with other metals and alloys, results in increases in yield strength and, to a lesser extent, in ultimate tensile strength and reductions in the capacity for work-hardening and in uniform elongation. These changes are much more severe in ferritic steels than in austenitic steels. In addition, the radiation induced increases in the ductile—brittle transition temperatures of the former steels are of major technological concern.

A considerable amount of experimental work, mainly of a preliminary nature, has been done and further studies are required to determine accurately the influences of the irradiation variables (temperature, integrated neutron dose, and neutron spectrum) and metallurgical variables (grain size, carbide size and distribution) on the susceptibility of steels to radiation damage. Further, the effort to date has been primarily devoted to studying the effects of neutron irradiation on the tensile and notched-bar properties and there is little or no information on the effects on the in-pile creep and fatigue properties.

Additional investigations are required on the kinetics of annealing of radiation damage in steels as a function of the integrated neutron dose, temperature of irradiation, and type of steel. The mechanism of radiation embrittlement has received some attention but this work needs to be extended to different types of steels exposed to neutron irradiation over a wide range of temperatures.

Both these and other aspects of radiation damage in steels are currently being studied in the UK and in the USA and it is hoped that the results which will eventually become available will lead to a better, if not complete, understanding of the problem.

References

16. Cottrell, A. H., Brittleness in Metals Conference, Culcheth Laboratories, 1st November, 1957, Paper 1, UKAEA IG Report 145 (RD/C), 1959.
17. Hull, D. and Mogford, I., AERE Report M/R 2555, April 1958.
18. Mogford, I., Churchman, A. T. and Hull, D., AERE Report M/R 2485, February 1958.
19. Makin, M. J., *et al.*, Int. Conf. Peaceful Uses Atomic Energy, 1958, Paper No. 80.
20. Wilson, J. C. and Sisman, O., Oak Ridge National Laboratory, Report ORNL-2829, December 1959, p 207.
21. Harries, D. R., Proc. USAEC Conf. The status of radiation effects research on structural materials and the implications to reactor design, Chicago, Oct. 1959, to be published.
22. Berggren, R. G., *ibid.*
23. Harries, D. R. and Judge, C., AERE Report M/M 219, Part 2, January 1959.
24. Hunter, J. R. and Alger, J. V., Proc. USAEC Conf. The status of radiation effects on structural materials and the implications to reactor design, Oct. 1959, to be published.
25. Harries, D. R. and Judge, C., Brittleness in Metals Conference, Culcheth Laboratories, 1st November 1957, Paper 5, UKAEA IG Report 145 (RD/C), 1959.
26. Burnett, R. C., Allen, J. M. N. and Harries, D. R., AERE Report M/R 2536, April 1958.
27. Leeser, D. O., ASTM Special Technical Publication No. 208, July 1957, p. 154.
28. Wilson, J. C. and Billington, D. S., Nuclear Engineering and Science Congress, Cleveland, 1955, Preprint 91.
29. Faris, F. E., Int. Conf. Peaceful Uses Atomic Energy, 1955, Paper No. 747.
30. Joseph, J. W., USAEC Report DP-369, June 1959.
31. Sutton, C. R. and Leeser, D. O., *Nucleonics*, 1954, **12**, (9), 8.
32. Reynolds, M. B., Low, J. R. and Sullivan, L. O., *J. of Metals*, 1955, **7**, (4), 555.
33. Bailey, R. E. and Silliman, M. A., ASTM Special Technical Publication No. 233, 1958, p. 85.
34. Bleiberg, M. L., USAEC Report WAPD-T-206, October 1955.
35. Murphy, W. F. and Paine, S. H., ASTM Special Technical Publication No. 208, July 1957, p. 162.

Cross Section by GRACCHUS

NO ONE is likely to dispute that the recent visit to the Berkeley nuclear station arranged by AEI was as smoothly organized as it was completely successful. From the moment we arrived at Paddington for the train to Gloucester everything ran faultlessly, even British Railways and its catering service. The organizing ability of an efficient industrial group made itself apparent at every stage, particularly on the site and in the reactor building. Conditions at Berkeley are particularly happy ones where, with a total labour force of 1600 working on a site area of 96 acres, loss of work time through disputes has been relatively small.

Civil engineering work, which began in January 1957 and included the excavation of some 200,000 cubic yards of material and the placing of nearly 132,000 cubic yards of concrete, is virtually completed. The great cranes and derricks have been dismantled and the emphasis now is on reactor installation. The first layer of the graphite blocks in the pressure vessel of No. 1 reactor is ready to receive subsequent layers—in all ten thousand separate pieces.

Visiting the pressure vessel was the highlight of the day, for we were the last outsiders to see at close quarters the core construction pattern. The insistence on clean conditions was brought home forcibly when we had to strip to underpants and don special clothing to prevent buttons, dust and moisture entering the pressure vessel.

There have been difficulties, however; last minute alarms over the effect of prolonged irradiation on graphite necessitated the fastening of steel bands round the graphite to contain the expansion forecasted. Then it was learnt that some shrinkage could be anticipated. Pins of zirconium metal were therefore added to prevent the graphite from rattling. The MRC revision of radiation safety standards caused further modifications. What trouble will follow it is impossible to say, but the work is going on and it is hoped to commission the first reactor by the spring of next year.

FROM ANOTHER nuclear power station site, Trawsfynydd, comes news about the first spot of labour trouble. A strike was started by 110 carpenters after negotiations over a bonus scheme had broken down, and dissatisfaction soon spread to the labourers, drillers and drivers, finally affecting about 1000 men. I was glad to see that the stoppage ended some twelve hours later, following discussions between the management and union officials. This quick settlement of trouble on the spot leads one to believe that Mr. Robens has already been instrumental in laying sound foundations for the future; after all disputes are bound to arise from time to time and it is essential to have an agreed procedure for dealing with them speedily.

DISAFFECTION among professional and technical civil servants is not usually a matter for coordinated action and it was with interest that I learnt of the one-day 'strike' at Harwell by the scientists and engineers belonging to the Institute of Professional Civil Servants. The cause of the trouble was a promotion plan whereby non-technical staff would have received better pay and promotion prospects than the scientific and technical grades. The Authority has been losing men for some time and it seems that the patience of the professional staff is finally exhausted. Anyhow, the outcome of the most respectable strike in the history of labour relations was an undertaking by AEA to drop the promotion plan.

HUMAN problems in engineering and industry is a necessary study if we are to avoid loss of time, accidents and bad workmanship. These are the points that have been made by various industrialists over the past few months.

Mr. C. C. Pounder, Director of Harland and Wolff, in discussing these problems at the Institute of Marine Engineers recently, related them primarily to the field of marine engineering. Much of his philosophy however was of general significance and I particularly liked his analysis of *homo sapiens:* a compound of 96 per cent. emotions, passions, prejudices, irrationalities, idiosyncrasies, fancies and whims, and 4 per cent. reason. No one with experience in management is likely to disagree that in dealing with a difficult fellow it is more important to concentrate on his emotional reactions and to arrive at a *modus vivendi*, with the 96% of him, if positive results are to be achieved, than to probe for the elusive 4% only to be disappointed with the outcome.

On the question of qualifications, Mr. Pounder said he disliked the use of 'expert' and 'scientist' and he deplored the grouping of engineers with scientists; their functions were widely different and the successful exercise of engineering needed a considerable knowledge of a technical nature. The engineer called in the scientist to assist him with problems of metallurgy, physics and chemistry; but he did the same with lawyers, patent agents and so on.

When it came to operating nuclear propelled merchant ships 'it must be the engineer who will control and be responsible for the machinery design and arrangements,' he said. 'It will be the engineer who will be responsible for the execution of the work. The highly meritorious labours of the scientist will—or should—begin and end at the nuclear reactor and its ancillaries, with all their manifold and intricate problems.'

NUCLEAR engineers and their operational reactions have received the attention of a three-man team from GEC. These 'human engineering' experts have just completed their study of control operations in nuclear power stations. Boredom of the control room staff leading to inattentiveness was probably the most acute problem. The team recommended that the control room should always have at least two, or preferably three men in it on the grounds that one man would become bored and possibly careless in his own company. The control room operators should also be able to do their work either standing up or sitting down. Dr. Ely, who led the team, said that 'all shifting of posture is beneficial' and should postpone the onset of boredom. It was also suggested that the control room should be small and compact, very much like the bridge of a ship, instead of the 'cathedral-like' control centres found in conventional power stations. The team also suggested that nuclear power plants should be equipped with computers. These would have three main functions: first, to be available for the physicist working on the station, second, to provide a training programme—simulating emergency and other control situations, and third to provide a prediction of the future state of the reactor as a result of any action taken by the control staff.

Our new series starts by indicating the instruments that are needed and what they have to do. Later articles will deal with detailed design

Health physics instrumentation—1

by Denis Taylor, M.Sc., Ph.D., M.I.E.E., F.Inst.P.
Plessey Nucleonics Ltd.

AN IMPORTANT ASPECT of health physics is the provision of suitable instruments to measure and characterize the radiations which constitute a hazard. Many of the familiar instruments of today, e.g. tissue-equivalent ionization chambers, quartz-fibre dosimeters, etc., owe their origin, in fact, to a health physics instrument need.

Health physics instruments also find application (or will do in the event of nuclear warfare) in the field of civil defence. Many health physics instruments have been designed and manufactured in quantity for civil defence applications, and have resulted in cheaper, better engineered, and more robust instruments being available for health physics purposes.

Health physics instruments are sometimes called health monitors. Monitoring may be defined as the periodic or continuous determination of the amount of ionizing radiation or radioactive contamination present in a specified region (area monitoring), or in or upon a person or his clothing (personnel monitoring), or in the atmosphere (air monitoring), or in the water (water monitoring).

Monitoring may be carried out as a safety measure for purposes of health protection, or to assess and sometimes control the operation of a machine producing ionizing radiations. The term 'health monitors' is used to cover all the instruments employed for these various purposes.

Classification

There are many classifications of health physics instruments or health monitors. One useful classification (*1*) is:

1. Instruments for the determination of the external exposure to which an individual may be, or has been exposed,
2. Instruments for the evaluation of the radioactivity on personnel, their clothing, on laboratory apparatus, laboratory benches and floors, in liquids or gases,
3. Instruments for the determination of radioactive materials deposited within individuals.

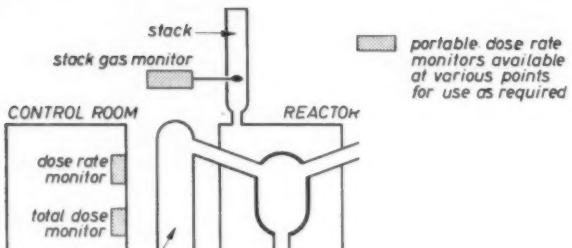
External exposure to which people may be subjected is determined by a variety of instruments known as survey meters, or (as they are employed to measure the radiation dose rate) dose-rate monitors. Some of these instruments are portable and may be carried from place to place to determine the dose-rate pattern around radioactive sources in use in a laboratory, around a machine producing ionizing radiation, or around a nuclear reactor plant. Other dose-rate monitors are fixed in location and are often used to monitor the dose-rate at a fixed location, say in the working space around a machine producing ionizing radiation, or around a nuclear reactor plant.

One or several detector heads may be used to provide a reasonably complete monitoring service. Dose-rate monitors may be designed to measure several types and energies of radiation and may use a variety of detecting elements, mechanical arrangements or electronic circuits.

Special instruments are employed to measure the external exposure actually experienced by individuals. These latter measure the accumulated (or integrated) radiation dose over a period of time (often a working day) and are called dosemeters (sometimes dosimeters). Again they may be portable and carried on the person. They are then called personnel dosemeters. Sometimes, like the corresponding dose-rate meters, they may be used in fixed locations. Dose-rate meters are used for assessing the possible hazards before exposure for any length of time is experienced. Personnel dosemeters on the other hand are used to measure the actual exposure experienced. In some cases it is necessary for dosemeters to be of the direct-reading type so that the wearer may make a periodic check on the accumulated radiation dose which he has experienced. In other cases when it is not convenient for the wearer to make a periodic check of the accumulated dose received (e.g. in the case of an operative working temporarily in a hot cell and wearing protective clothing) and it is then an advantage for the instrument to be provided with alarm facilities. Such instruments are often provided with an aural alarm which operates when the accumulated dose reaches some pre-set figure.

Dose-rate meters and dosemeters are designed for monitoring all types of radiation and it is sometimes convenient to designate the instruments according to the type

> *Health physics has been defined (National Research Council, USA) as that branch of radiological physics dealing with the protection of personnel from harmful effects of ionizing radiation. It includes the routine procedures of radiation protection surveys, area and personnel monitoring, the recommendation of appropriate protective equipment and procedures, the determination of acceptable standards of operation, and the solution of problems incident to the effective protection of all persons from harmful effects of radiation.*



Health physics monitoring around a reactor (Fig. 1)

of radiation being measured. Thus there are neutron survey meters, gamma dosemeters, beta dose-rate monitors. Some instruments are provided with a range of detector probes which may be connected to the main instrument when required for monitoring one type of radiation, or another. Such instruments are usually designated general-purpose dose-rate monitors or general-purpose dosemeters.

In many situations of radiation exposure, dosimetry is difficult because of the presence of more than one type of radiation. It is usual at the present time to monitor each type of radiation separately with different instruments (or one general-purpose instrument used with a series of different detector-probes in turn) and sum the effect of these different hazards. In some cases it is known that one radiation hazard is predominant and it is then possible to ignore radiation hazards due to other types of radiation. There is, however, a need for health monitors for measuring the biological effect of mixed radiation (say neutron plus gamma-radiation). Few instruments of this type exist at the present time, but it seems likely that they will become available in due course.

Contamination monitors

The instruments in the second class are all concerned with the evaluation of radioactive contamination. It is natural, therefore, for this class of instrument to be called contamination monitors. Again, these are general-purpose contamination monitors. They are usually instruments provided with a multiplicity of detector-probes for specific types of measurement, e.g. alpha-active contamination, gamma-activity contamination, etc. These instruments usually measure the total alpha-activity, total-gamma-activity, etc., but sometimes the measurement involves the determination of the gamma radiation at a selected gamma energy, and can then be specific for a particular nuclide. Thus, there are instruments for checking Pu-239 contamination by monitoring the 17 keV gamma-emissions and U-235 contamination by monitoring the 184 keV gamma-emissions, etc.

There are also many special-purpose contamination monitors. These are usually classified according to their function. A good example is the clothing monitor, which is used for checking possible radioactive contamination on personnel and their clothing. Other special purpose contamination monitors are water monitors, food monitors, milk monitors, etc.

Whole body monitors

In large laboratories handling radioactive materials it is usual to employ special apparatus for monitoring personnel suspected for having inhaled or ingested radioactive material. There are two basic methods of measuring the body burden of radioactive materials of living subjects. The first is by excretion studies and depends on having data on the fractions excreted. The second is by measurement of the external radiation from the body, and necessitates making assumptions about the location of the contaminant and the absorption of the radiation in the body. This second method has become very popular in recent years.

Health instruments at reactor sites

Large numbers of health monitoring instruments are required for use at reactor sites. There is, as yet, no complete agreement as to exactly what is required, but the following list is typical (2):

	INSTRUMENT	PURPOSE
1.	*Installed and portable dose-rate monitors for gamma, slow neutron and fast radiation*	Monitoring of reactor buildings and general site area
2.	*Portable accumulated dosemeters*	Monitoring of dose received by personnel in reactor buildings and cooling pond area
3.	*Air sampling equipment*	Monitoring of air in reactor
4.	*Hand and clothing monitors*	Monitoring of personnel and their clothing in change rooms
5.	*Clothing monitors*	Monitoring of clothing, etc., in active laundry
6.	*General purpose contamination monitors*	Monitoring of equipment, benches, floor, etc., in reactor buildings, pond area, etc.
7.	*Liquid effluent monitors*	Monitoring of liquid effluents from effluent farm, etc.
8.	*Gaseous effluent monitors (sometimes called stack monitors)*	Monitoring of gaseous effluents from reactor stack
9.	*Apparatus for radioactive assay comprising geiger counters, scintillation counters, scalers, power units, etc.*	For use in health physics laboratories for checking the activity of biological samples, smear test samples, etc.
10.	*Survey vans fitted with apparatus for general activity measurements and dose-rate measurements*	Monitoring in site area and in the vicinity of site

Figure 1 summarizes these various requirements.

Conclusion

In the later articles of this series it is proposed to discuss the design of each of the main instruments mentioned in this introductory survey and to give examples of completed designs of typical instruments.

References :

1. Kuper, J. B. H. 'Radiation, Biology and Medicine,' ch. 18, ed. Claus, W. D. 1958, Mass., USA, Addison-Wesley.
2. Taylor, D. NUCLEAR POWER YEAR BOOK 1958/9, 4–44.

New Product Survey

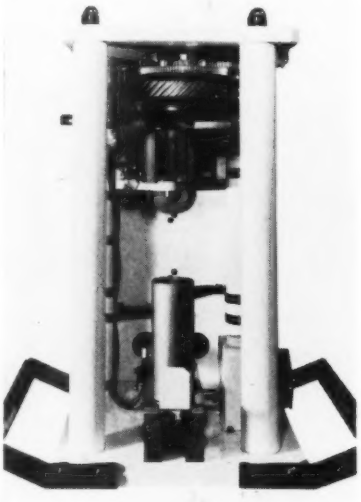
PLANT · EQUIPMENT · INSTRUMENTS · MATERIALS

IN FRANCE THIS MONTH

FUEL DECANNING
manual and automatic

The Siersatom fuel element can openers have many applications. A manual type opens tubes of 1 in. diameter whilst a semi-automatic model cuts tubes of 1–2 in. and can be used with a manipulator. An automatic model is available for tubes of 1 in. dia. × 3 in. height and for burst fuel elements, a semi-automatic type is made to rotate or swivel. Another works in two planes for cutting both ends of the can.

The latest universal type A6300 separates burst elements or tubes ½–2 in. of varying lengths. Easy replacement of the cutting tool allows rapid changeover for different materials such as zirconium, magnesium, aluminium, stainless steel,



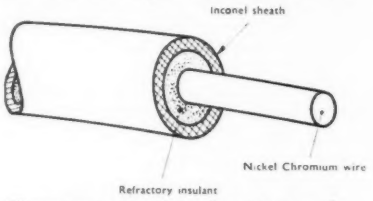
The Siersatom A15 type opener is automatic and cuts stainless steel or zirconium tubes

Tick **No 231** on reply card

FURNACE HEATING
high insulation elements

For heating materials up to 1000°C either in vacuum or under pressure, SODERN have introduced the *Thermocoax* heating element which consists of a nickel-chromium alloy inner conductor surrounded by an insulating layer of highly compressed powdered magnesium oxide and an outer casing of Inconel. The elements may be wound directly round the object to be heated without further insulation and hermetic seals are easily obtained by first brazing the outer sheath into a bushing.

The response to overall heating is rapid because of the time lag (about one second) between inner conductor and sheath, the latter making intimate contact with the object being heated. The

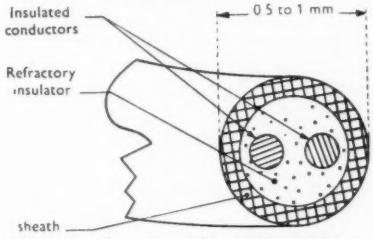


Thermocoax heating elements can be wound directly round an object and give rapid overall heating without further insulation

types of elements available range from 1 mm to 2 mm o.d., with resistance 4 to 0·88 ohm/ft, and maximum permissible current 8 to 32 amp. Rolls can be obtained in standard lengths of 250–280 ft (1 mm) and 65–75 ft (2 mm).

If *Thermocoax* miniature thermocouples are used as the temperature sensing elements, the problem of automatic temperature regulation can be greatly simplified. A relatively simple 'on-off'-type control will provide good temperature stability. The Thermocoax thermoelectric microconductors consist of a sheath in stainless steel to give mechanical, chemical and electrical protection, within which are placed two conductors of Chromel and Alumel forming the two elements of the thermocouple. They are insulated from the other and from the sheath by magnesia. The thermocouple itself is made by welding the ends of the two insulated conductors.

External diameter of the three types available varies from 0·5 mm to 1 mm with standard lengths 115–150 ft, or 490 ft for the thinner type. Because of the small diameter and the finely divided state of the refractory material, *Thermo-*



Miniature thermocouples can be used as temperature sensing elements

coax can be readily bent and the great length frequently enables the use of compensating lines to be avoided.

Tick **No 232** on reply card

GAMMA TESTER
for 7-inch steel

The latest production in Gamma Industrie's range of gammagraphy equipment is the Gammatron GTM-2T unit, designed for gamma-ray testing of steel thicknesses up to 7 inches, with relatively short time exposures. It contains cobalt-60 sources up to 2000 curies with radiation to the order of 2 mr/h at 3 ft from the unit.

The body consists of a waterproof steel shell and through the radiation port, the beam can be directed around 360°. The source is ejected and brought back by electrical control situated at 10 ft or more from the unit. An emergency mechanical device brings the source back to its shielded position. A cell indicates at any time the position of the radioactive source and a spot indi-

Gammatron's GTM-2T which can be rotated 360° or swivelled, gives flexibility in measuring thicknesses of metals

cates the direction of the beam. The unit can be used either on a rotating stand or suspended from a fork and the weight is just over 2 tons.

Tick **No 233** on reply card

LEAK DETECTOR

miniature mass spectrometer

The THM 105A leak detector made by the Compagnie Française Thomson-Houston is based on the principle of detection of helium gas by a miniature mass spectrometer, and it is capable of detecting, locating and measuring leaks as small as 10^{-12} cm³ per second. The proportion of helium required in any other gas is as little as one part in ten millions. Response time is rapid and the power consumption is only 800 watts.

The spectrometric chamber employs double deflexion of 180° enabling greater operational stability and high sensitivity to be obtained. Two pumping units have been incorporated in the vacuum circuit;

Leaks of 10^{-12} cm³/s can be detected

one is a two-stage mechanical pump of high capacity, and the second a silicone oil vapour diffusion type cooled by compressed air. The pressure maintained in the test cavity can be reduced to below 10^{-6} mm of mercury.

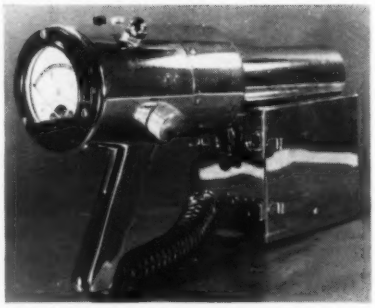
Tick **No 234** on reply card

GAMMA DETECTOR

transistorized counter

A new robust and leakproof scintillometer has been developed by Vilbert Lourmat for uranium prospecting and personnel protection that can be carried either on foot or in a car. The VL 151T is transistorized and works from nine 1·5 V torch batteries giving 350 hours continuous service.

It has a crystal type detector NaI(Tl) 1·5 in. × 1 in., calibration is by radium



Portable counter for uranium prospecting

lozenge and six scales permit gamma measurements of from 0·001 mr/h to 5 mr/h. The three time constants have been spread out from ½ s to 45 s to allow rapid readings in a moving car and a precise indication of locations.

Tick **No 235** on reply card

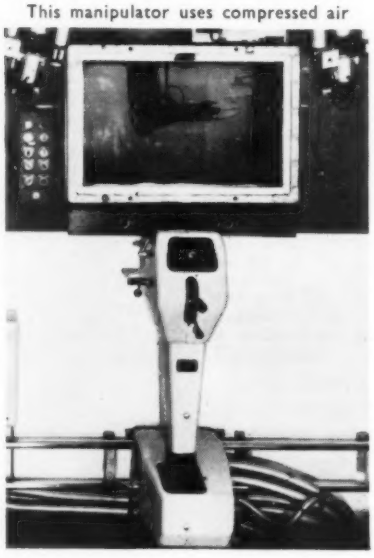
REMOTE CONTROL

pneumatic manipulator

The latest development in manipulators by the Société ERTN, type III, relies on compressed air as its main source of energy. Although designed for the manipulation of heavy objects by remote control, it is equally able to handle fragile objects or effect the decanting of liquids. The maximum weight that can be lifted by the horizontal grab is 214 lb. The use of compressed air and the avoidance of complex and fragile devices has resulted in an apparatus easy to decontaminate and requiring no maintenance.

The manipulator is very flexible, permitting the same articulations as the arm, elbow, wrist and hand. In the case of a breakdown in the air generator or of a leakage, the manipulator continues to function on an air reserve that allows sufficient time for the completion of a

This manipulator uses compressed air



movement or for the setting down of an object regardless of its weight.

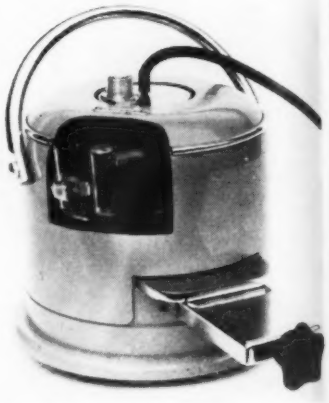
The assembly moves on tubular rails fixed to the cell walls at speeds varying between 1 to 10 cm/sec and translation movements are dictated by inclining the control post, following the direction that is to be imposed, forward or backward, left or right. Speed is greater with accentuation of the angle of inclination, and vice versa. Other movements are effected with the aid of manettes, so placed that the operator can act by instinct and without special training. The apparatus can be used at greater distances by linkage with a television circuit, and slave arm pick-ups permit the operation of the manipulator in several cells.

Tick **No 236** on reply card

GAS FLOW COUNTER

detects low energy radiations

The FCP 101 counter marketed by SAIP is a wall-less, continuous scanning 2γ-unit for high performance detection of



The FCP101 provides for proportional and geiger-müller counting

low penetration radiations. A lead shield, 5 cm thick, provides protection in all directions and reduces the background noise to a low level. The sample is placed in a cup hollowed into a metal blade which slides into an air-tight recess. It can be set in three positions: with the cup outside of the counter for changing the source, with the cup facing the scanning aperture, or with the cup inside the counter. The counter can be equipped with a 100 microgram/cm² window, in which case the counter can be used as any other counter.

The gaseous mixture which is 95% argon and 5% propane can be supplied in tanks of various capacity, the standard tank holding 53 pints under 150 atmospheres. It provides for counter operation in the proportional zone as well as in the geiger-müller zone.

The FC 102 instrument is a 4γ-counter for the detection of soft beta

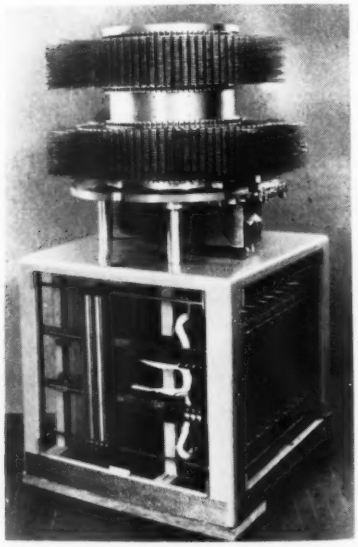
radiations from isotopes such as carbon-14, calcium-45 and sulphur-35. Source changing is possible within a time interval of one minute without disturbing the working conditions into the counter.

Tick **No 237** on reply card

DATA PROCESSING FOR EDF2

continuous operation

The development of numerical control in the EDF2 nuclear power plant for checks on temperature, pressure and other physical measurements was the responsibility of the Compagnie Industrielle des Téléphones. One of the main elements in the fully transistorized system devised is the numerical computer CITAC 210. Associated with this is the CCS1000 unit, an input element that is directly connected to the primary transmitters for converting physical measurements into electrical values, and operating their selection and conversion into a digital code compatible with the CITAC 210.



The main part of the CCS 1000 selector-and-coder is the mechanical selector; electronic controls are in the base

The maximum capacity is 1467 measurements per minute and the output delivers the numerical value (alpha numerical code) associated with an address. The coding accuracy is 0·5% and the noise in the passing band does not exceed 1 microvolt.

Tick **No 238** on reply card

BETA COUNTERS

weak sources measured

The measurement of extremely weak sources of beta emitting substances which result in counting rates of the order of a few tenths of a count per minute requires a background reduction in the counting set-up. Intertechnique have introduced the ECF101 and 103 with mechanical shielding and electronic shielding that prevents extraneous radiation from reaching the counting chambers. Since these systems are bulky and heavy, two independent counting chambers are enclosed in each instrument.

Individual pulses received in each counting chamber are recorded on a strip chart recorder, a method that is particularly suitable for lengthy measurements of low activity samples. An 8 in. thick iron shield stops most external gamma rays and a considerable proportion of cosmic rays. Any of the latter which have not been stopped are eliminated by a screen of 28 cosmic type geiger tubes surrounding the counting chambers. These tubes are all connected in parallel and they are electronically in anti-coincidence with each counting chamber. Pure bismuth cylinders which surround each chamber stop gamma rays emitted by radioactive impurities in the iron shield.

Tick **No 239** on reply card

IN BRIEF

New metals. Among the new metals produced by Kuhlmann are molybdenum, columbium and vanadium of high purity in the form of metal powder, sintered blocks or pellets and salts (oxides, carbides, etc.). With the collaboration of Société Métallurgique d'Imphy, a French steel plant, arc-cast ingots are transformed into bars, sheets and tubes.

Tick **No 240** on reply card

Safe handling. A wide range of equipment for hot laboratories is marketed by SIERSATOM and includes single or multiple operated glove boxes, high capacity cable operated manipulators, master-slave and magnetically operated manipulators. Automatic and semi-automatic can openers are also available for aluminium, stainless steel and zirconium elements.

Tick **No 241** on reply card

Instrumentation. Compagnie Française Thomson-Houston have been responsible for part of the instrumentation in the French reactor programme and among the products now available are linear and logarithmic d.c. amplifiers, period meters, and transfer-phasemeters for the determination of reactor characteristics. Their range of spectrometers can be applied to the assaying of light elements, deuterium and lithium.

Tick **No 242** on reply card

Radiation detectors. The latest scintillation detector for low energy beta emitters available from SAIP has a 2 in. photocathode photo-multiplier cooled by a continuous flow of water in a water-jacket. With a motor-driven drum for scanning, three speeds are selected by external commutator. Weight is 53 lb. Another instrument available is the Gamma-Relay suitable for heavy duty industrial uses. The source unit is of cobalt-60 or caesium-137 accommodated in a lead shield, whilst the receiver unit comprises a geiger counter and a pulse-shaping circuit including four transistors.

Tick **No 243** on reply card

Isotope separator. The EM-2 type of isotope separators developed by Gamma Industrie relies on the action of a magnetic field deflecting an ion beam accelerated by an electric field. The unit will separate isotopes of mass 150 from those of 149 or 151 and by reducing ion flow and width of beam, separating power reaches 300.

Tick **No 244** on reply card

Portable detector. Radiation detector DABG 101 available from Intertechnique uses two impulse detectors: a geiger counter and a scintillation counter. The apparatus is entirely transistorized and weighs about 12 lb. It can be used to measure alpha, beta and gamma radiations and fast neutron emissions.

Tick **No 245** on reply card

Sintered products. Metafram's range of sintered nuclear accessories includes self-lubricating bearings in iron, nickel, or stainless steel, impregnated with a high percentage of Mo S2. Also available (for reactor liquid or gas purification circuits) are filters made of bronze, nickel or stainless steel. The company supplies control rods and other parts in boron carbide and aluminium.

Tick **No 246** on reply card

Gravitometer. SAIP's gamma-ray gravitometer can be used for pipe-line measurement, thickness control, continuous weighing and for the regulation of liquids. The detector unit is an ionization chamber filled with argon at 150 atmos. Power requirements are 110 or 220 V, 50 cycles, with total consumption 100 VA.

Tick **No 247** on reply card

Leak-proof valves. Stainless steel valves and cocks for work at temperatures up to 580° are available from Techniques Nucléaires. All valve joints are welded for use in liquid metal, heavy water and other circuits at a working pressure of 14–28 lb/in². Entire construction of the miniature pressure cocks is from stainless steel bonded with 18/8 Mo to ensure protection against porosity. Pressure joint have been replaced with weldless bellows.

Tick **No 248** on reply card

Canned pumps. Jeumont, in collaboration with Rateau, have developed a range of canned motor pumps giving a power of 190 h.p. at 1500 rev/min, made in stainless steel, for use in heavy water and other radioactive circuits.

Tick **No 249** on reply card

INDUSTRIAL NEWSDESK

$N(CH_2COOH)_2$ washes whiter

Some detergent compositions have been specially compounded by the Atomic Energy Authority to remove contamination by radioactive metals and their salts. One of these detergents, which has been patented and for which the Atomic Energy Authority has so far granted one manufacturing licence (it will not reveal to whom), can deal successfully with contamination even when chemically bound to working surfaces or to clothing.

The compound comes in various forms; for example a cream made by adding a thickening agent such as sodium alginate, which can be brushed and spread on to large objects, or a powder including an abrasive such as powdered pumice for use when contamination has penetrated some way into the surface to be treated. Practically any material can be dealt with, claims the Atomic Energy Authority, including textiles, plastics, paints, rubber, and metals. The basic idea of the process is that a more efficient removal of radioactive metal contamination is achieved when an autonic complex is formed by the metal and a water soluble polycarboxylic acid containing the group $N(CH_2COOH)_2$.

Martins study Russian device

A Russian-built thermoelectric generator, used to convert heat from a kerosene lamp into electricity for radios in remote Asian areas, is being examined carefully by a group of scientists at the United States Martin Company, where similar 'direct conversion' principles have already been applied to nuclear heat sources. The bulky 20 lb Russian device has been in production for at least two years, but the Soviet Embassy in Washington had been ineffective (though helpful), and it was only after long correspondence with various holding companies that a model was located in Colnbrook, Bucks, England. The device, incidentally, bears the English inscription: 'Made in USSR.' The cost: £20.

In the generator, a series of thermocouples is arranged around the upper portion of a kerosene lamp. As each set of elements is heated at one end by the lamp, a small amount of electricity flows through the pair. Metallic fins remove the excess heat. The same basic principle is used in Martin's SNAP units (systems of nuclear auxiliary power) (see January p 75), but in these the heat is supplied by the decay of a small amount of tightly-sealed radioactive material.

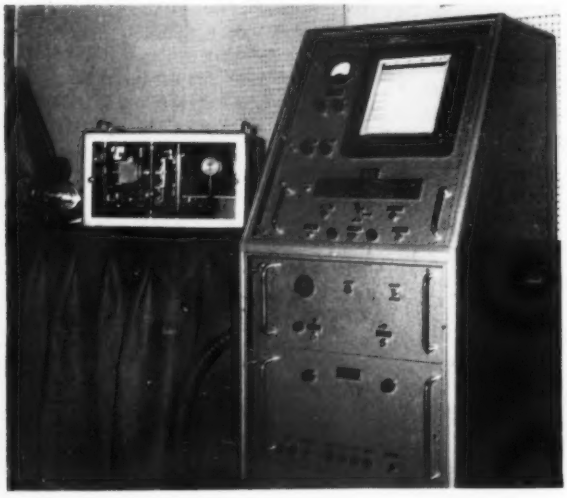
The Energy Conversion Group studying the unit was set up recently by The Martin Company to press research in thermoelectricity and other means of converting heat directly into electricity without the use of moving parts. Eventually, such methods will be used in connexion with nuclear reactors, says the company. The group, under the direction of Dr. Mostafa E. Talaat, is examining the kerosene-fuelled generator to evaluate the state of Russian technology in direct conversion.

The Energy Conversion Group had an international flavour even before the new import. Besides Egyptian-born Dr. Talaat, it includes Dr. Cheng Shih, a native of China; and Dr. Walter B. Bienert, of the Federal Republic of Germany.

Martin's vice-president, J. Donald Rauth (right) and Dr. Mostafa E. Talaat, head of a new Energy Conversion Group in the Nuclear Division, examine the Russian thermoelectric generator using similar principles to SNAP-3

ASLIB courses popular

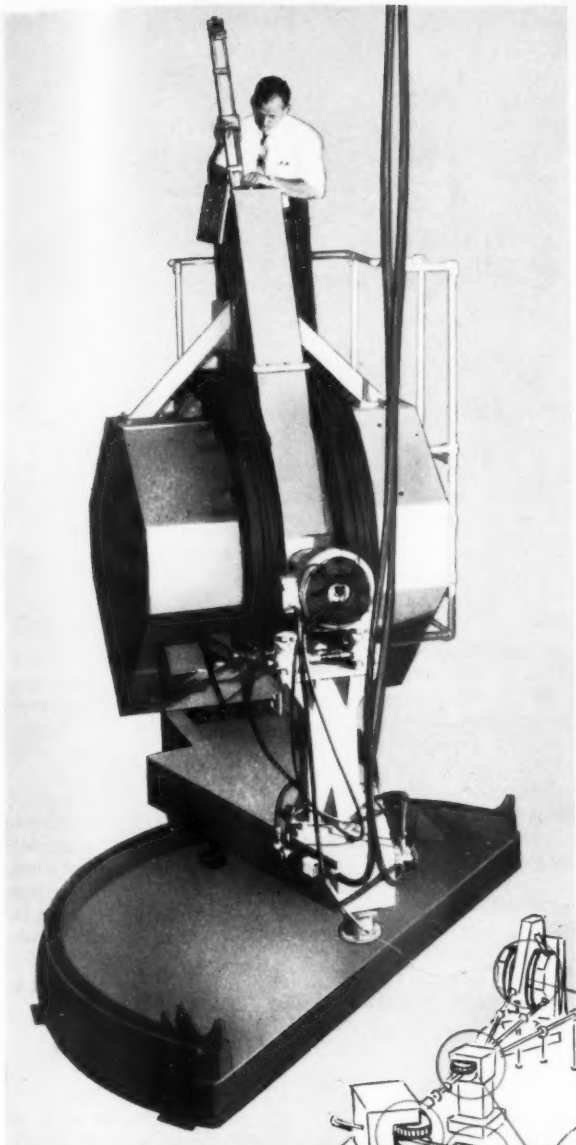
The courses run by the ASLIB Association on the Compilation and Production of Information Department Publications have been very much in demand. In the latest of the series NUCLEAR POWER's Assistant Editor, Mr. J. Burkett, spoke about the problems and methods of reproduction. Some forty concerns were represented; they included BICC, Richard Costain, English Electric Co., Ericsson Telephones, Formica, GEC, ICI, Kents, John Laing, Metal Box, the National Coal Board, The British Rubber



Reducing beryllium risk

In this Atomic Energy Authority-developed beryllium monitor, which was shown at the Physical Society show, the air to be sampled is drawn through a specially designed chamber in which any beryllium present is optically excited as it passes through a triggered alternating current arc. The ultra-violet radiations from this source are then resolved into their components by means of a small spectrograph, which is specially designed to have a high dispersive power. The intensity of the beryllium doublet at 3130 A, which is proportional to the concentration of beryllium present in the air being monitored, is measured photo electrically and then recorded on a chart.

The apparatus is fully automatic and it will operate on a predetermined cycle in which it is first calibrated and then records a series of results, at one minute intervals. The results produced are quantitative over the range of concentration from 1–75 millionths of a gram of beryllium per cubic meter.



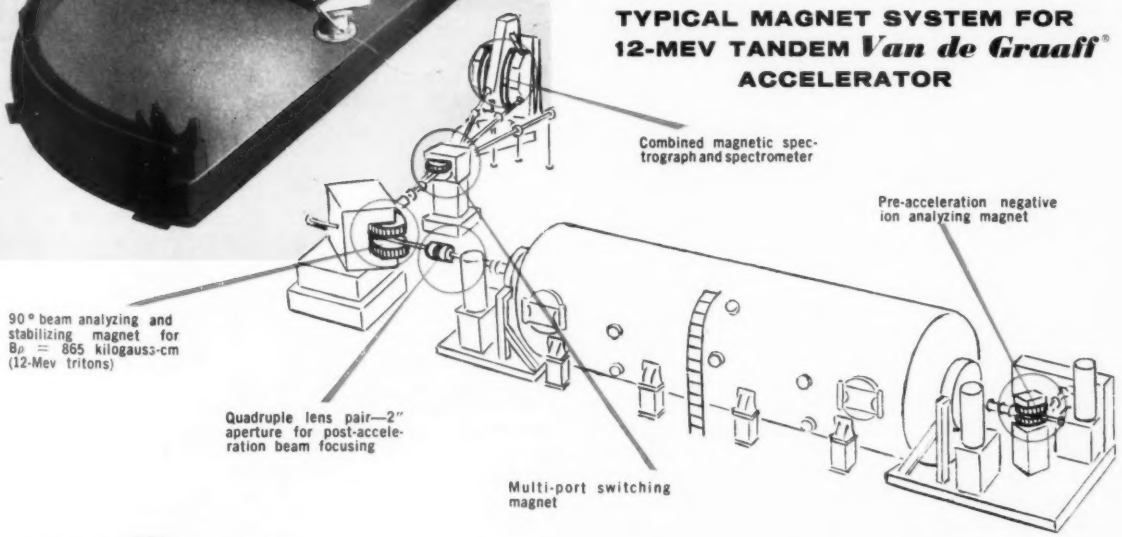
NUCLEAR PARTICLE ANALYZING MAGNETS

Combined Magnetic Spectrograph and Spectrometer* designed and built for Chalk River Laboratories, Atomic Energy of Canada, Ltd., for energy analysis of protons, deuterons, and alpha particles.

- Magnetic rigidity —
  Up to $B\rho = 865$ kilogauss-cm (12-Mev tritons)
- Resolving power (spectrograph) —
  $E/\Delta E = 10^3$ or better
- Solid angle (spectrograph) —
  $\Omega = 1.4 \times 10^{-3}$ steradians (max)
- Solid angle (spectrometer) —
  $\Omega = 0.9 \times 10^{-2}$ steradians (max)
- Reaction angle —
  $\theta = 0$ to 135 degrees
- Detector —
  Nuclear track plate and scintillation counter

*For further technical reference, see H.A. Enge, RSI **29**, 885 (1958)

TYPICAL MAGNET SYSTEM FOR 12-MEV TANDEM *Van de Graaff*® ACCELERATOR


Combined magnetic spectrograph and spectrometer
Pre-acceleration negative ion analyzing magnet
90° beam analyzing and stabilizing magnet for Bρ = 865 kilogauss-cm (12-Mev tritons)
Quadruple lens pair—2" aperture for post-acceleration beam focusing
Multi-port switching magnet

For detailed information on magnets and accelerators, write to Technical Sales:

HIGH VOLTAGE ENGINEERING CORPORATION

BURLINGTON, MASSACHUSETTS – U. S. A.

Tick **No 108** on reply card for further details

Manufacturers Research Association, Royal Military College of Science, Rubery Owen, Shell International Chemicals, Taylor Woodrow, Unilever, the UKAEA, C. C. Wakefield and the War Office.

AEA's IBM works hard

The Atomic Energy Authority's IBM 709 computer is now clocking up 155 hours a week, working for three shifts a day, seven days a week. Scheduled maintenance time is averaging ten hours a week and difficulties or faulty operation are absorbing only three hours.

Bought in 1959, the computer is the most powerful data processing system in Europe at the moment; it can execute more than 40,000 instructions per second and provides four channels which allow independent transmission of information to and from the high speed storage unit, whilst the processing unit is simultaneously carrying out other calculations. The system consists of 28 interconnected units.

EMI link with US firm

Under a recent agreement, EMI Electronics will in future have the benefit of the New York Fairbanks Whitney Corporation's coast to coast marketing organization. This group, which with its subsidiary companies employs some 12,000 people, manufactures products ranging from machine tools, diesel electric locomotives, and electric power generators to aircraft engine accessories and missile components; it has undertaken to market most of EMI's range of electronic equipment, and some will also be manufactured in the US under licence.

According to Clifford Metcalfe, EMI's managing director, who describes the arrangement as a 'natural marriage,' the flow of information and products will not be one way only: 'Certain equipment developed by the American company will be marketed by us in the UK and Europe, and we are also going to study the possibility of a joint venture in the electronics field in the European Common Market.' After the agreement, David Karr, president of Fairbanks Whitney, handed the British company a bouquet: 'We are proud to be associated with the eminent industrial and scientific leadership of EMI Electronics.' The agreement, he said, is to be implemented straight away by installing two Emidec 1100 transistorized computers.

Among the EMI products that will now be marketed by the US company are nuclear health instruments. The existing American representatives, H. L. Hoffman & Co. of Westbury, Long Island, have cooperated in forming the agreement and will continue to deal with some of EMI's products.

HINKLEY GRAPHITE READY These thousands of tons of graphite bricks needed for the reactors at the Hinkley Point atomic power station are being stored at West Zoyland, near Bridgwater, Somerset. Soon work will start in loading them into the pressure vessels and interlocking them to form the cores. The bricks are machined to an accuracy of a thousandth of an inch in a specially built and equipped processing shop at Whetstone, near Leicester, the centre of English Electric's Atomic Power Division. One or two lorry loads leave Whetstone for Bridgwater every day

Castrol House opened

The new £M2¼ international headquarters of the Wakefield Castrol Group, Castrol House, was officially opened a few weeks ago by the Rt. Hon. Ernest Marples, M.P., Minister of Transport. The building, which is fifteen stories high, covers a site of nearly one acre and houses some 800 people. With its twelve-storey glass tower, internally floodlit at night, it dominates the Marylebone area in London.

The Group, which is the largest independent lubricating oil concern in the world, with an annual net profit of £M1½, controls 22 companies in various parts of the the world and many branches in the Commonwealth. It is the market leader in lubrication in the UK supplying many industries. Castrol lubricants are used in CEGB turbines and in the UKAEA establishments. For moving parts subjected to radiation, a radiation-resistant oil 'Nucleol' has been developed.

French G3A gets under way

The new French concern, Groupement Atomique Alsacienne Atlantique (G3A), has been chosen by the Commissariat à l'Energie Atomique as general architect of the fast neutron breeder reactor Rapsodie to be built shortly in the South of France. G3A is a subsidiary of the Société Alsacienne de Constructions Mécaniques (SACM) and the Chantiers de l'Atlantique (Penhoët-Loire) which have both taken a large share in the development of the French atomic energy industry; Chantiers de l'Atlantique was industrial architect for the high flux research reactor EL3 and the Société Alsacienne for G2 and G3. G3A itself is made up of three divisions:

1. A Nuclear Experimental Studies Department located at the Centre of Arny, at Bruyères-le-Chatel, near Paris
2. An Industrial Studies Department
3. A Department called 'General Enterprise,' the last two departments being located at the Plessis-Robinson centre which has been built by the Chantiers de l'Atlantique, and transferred to the new company.

'By far the most important contribution made by the founding companies to G3A,' its President, M. Julia, told NUCLEAR POWER, 'is that of well-known personalities among the French experts in atomic energy, and that of the working teams which they have formed, who bring with them the experience gained from the various projects carried out by the parent companies.'

IN BRIEF

- **New company** Chemical Works Projects Ltd. has been formed by P. G. Engineering Limited (of the Power-Gas Group), Humphreys & Glasgow Ltd., and Simon-Carves Limited to supplement their normal activities by undertaking contracts for large chemical projects overseas.
- **Community coal stocks** Pithead coal stocks in the European Coal and Steel Community recorded another substantial fall in January, this time by 700,000 tons.
- **Idaho modifications** The US Atomic Energy Commission is to carry out £35,000 worth of building modifications and other miscellaneous construction work at the National Reactor Testing Station, Idaho.
- **US Babcock & Wilcox** Net income of £5·7 million for 1959 was 32% up on 1958.
- **US High Voltage Engineering** In 1959 sales rose by 23% on 1958 and net income, after tax, by 44%.

CAST IRON VESSELS

for the ATOMIC ENERGY AUTHORITY

Approved by Lloyd's for Class II welding for pressure vessels

One of the battery of special Cast Iron Vessels supplied to the U.K. Atomic Energy Authority. The body of the vessel is approximately 5ft. 8in. outside diameter by 6ft. 3in. high and the complete vessel weighs approximately 30 tons.

WIDNES

ESTABLISHED 1841

FOUNDRY & ENGINEERING CO. LTD.

LUGSDALE ROAD, WIDNES, LANCS. TEL. 2251/4. GRAMS. 'FOUNDRY WIDNES'

W 40

Tick **No 109** on reply card for further details

They said...

points from papers, speeches, conferences

New engineering materials

In recent years there has been an accumulation of evidence and feeling in this country that engineering design lacks the status it merits, according to Mr. J. Shapiro, design consultant, in a speech at the first conference on Engineering Materials and Design, which was held at Earls Court a few weeks ago. From the Exhibition and papers given by eminent authorities in engineering research and industry, it was evident that a good start has been made in changing the status.

'Designers may well feel that, in the modern jargon, management are "squares" if they expect high standards to flourish without their support and sympathy'. Mr. R. M. Kay, of AEI, advanced this view in explaining a special formula that he had devised for indicating in a compacted form the correct perspective for industrial design when considering the engineering industry. Management backing and urge is shown squared due to its high importance. 'I cannot stress strongly enough that without this encouragement from the management', said Mr. Kay, 'design standards cannot hope to prosper. It is essential to eliminate an amateur approach which is often only a matter of uninformed opinion.'

Vacuum techniques progress

Newly developed materials for high temperature and anti-corrosion applications were examined by various speakers. A significant development has been the growth during the last decade of vacuum melting from a small-scale laboratory technique to a large well established industrial process. 'The main stimulus to the growth of vacuum metallurgy, was the development of the reactive element titanium', said Mr. H. C. Child, of Jessop-Saville Ltd. No refractory materials were known which could resist this element and so there followed a series of developments starting from non-consumable tungsten electrode furnaces melting in argon, and leading gradually to the large consumable electrode vacuum arc furnaces known today.

Mr. Childs then examined the properties of the various types of materials now being vacuum melted: alpha, beta and alpha-beta alloys of titanium; martensitic chromium steels; austenitic steels and nickel base alloys; nickel base alloys; ball bearing materials; and ultra high tensile steels suitable for aircraft and missile structural components.

Beryllium: ductility is the snag

Titanium alloys offer the most attractive properties up to nearly 500°C but for applications in the temperature range 500–600°C chromium martensitic steels have attractive creep properties, he pointed out, whilst at temperatures of 600°C and above, it is necessary to use austenitic steels or nickel base alloys to obtain the highest creep strength. 'There is a growing interest' said Mr. Child 'in the use of steels at higher ultimate tensile strengths, that is above 100 ton/in². In this country the interest is centred on a 5% Cr-Mo-V steel (H.50) since a tensile strength of 120 ton/in² may be obtained even when the alloy is double tempered at 550°C'.

The Materials and Design Conference. Attendance was high

The development of special steels, particularly corrosion resistant types, was also the subject of a paper by Mr. J. I. Morley of Firth-Vickers Stainless Steels Ltd. Low carbon martensitic chromium-nickel steels, modifications of the well-known 18% chromium-8% nickel steels, had higher hardness and strength in addition to similar corrosion resistance, and these properties, he said, together with weldability, had not hitherto been combined in any one steel. A separate group, also new to industry, were the semi-austenitic precipitation hardening steels.

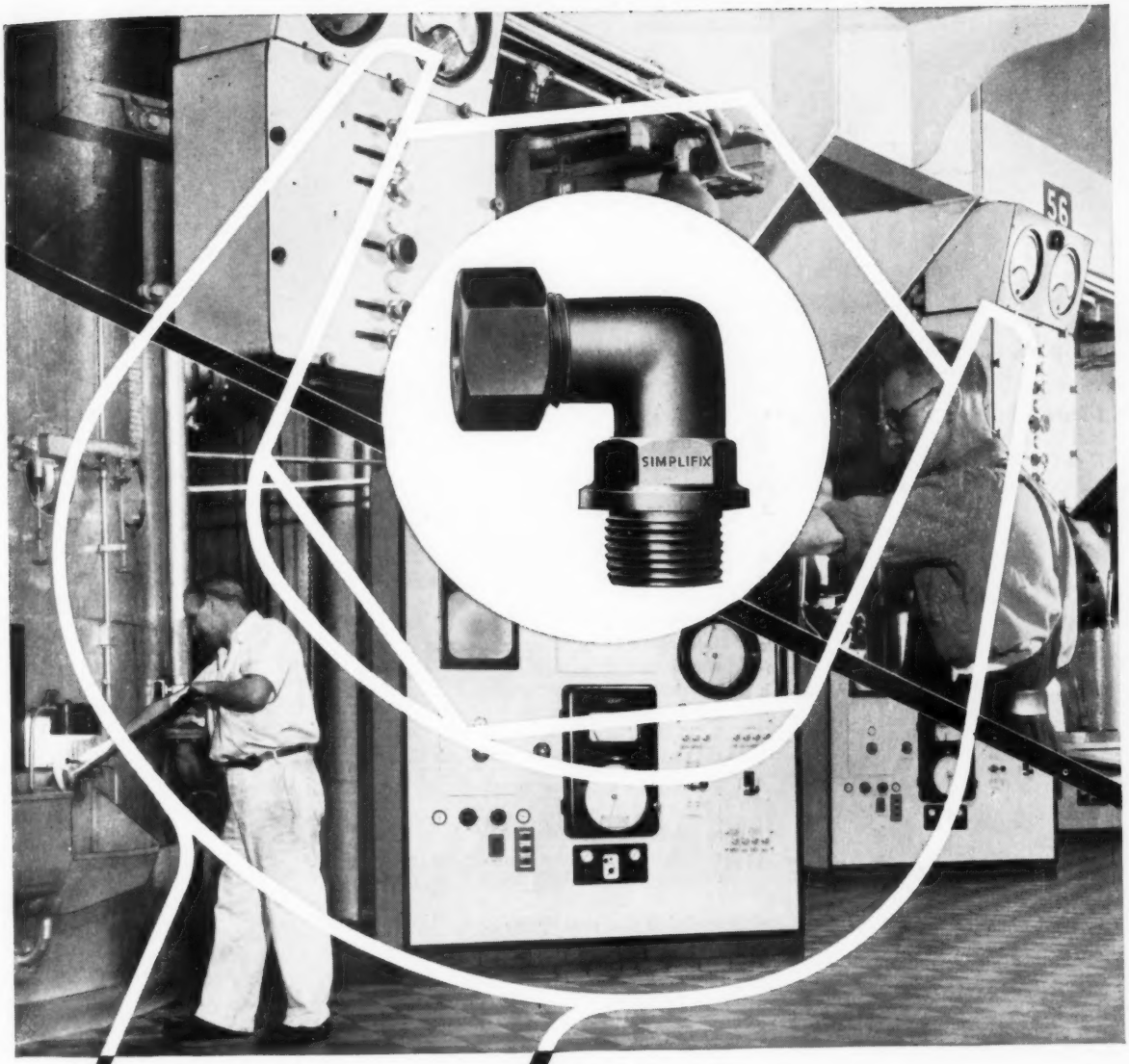
Among the low density metals that are likely to see increasing use by the engineering industry are magnesium and its alloys. Mr. Fisher, of Magnesium Elektron Ltd. said that the density of all commercial magnesium base alloys is 1·8–1·9 compared with about 2·8 for aluminium and about 7·2 for cast iron. 'In practice, the magnesium castings in the Volkswagen car weigh about 36 lb; the same items in cast iron would weigh some 140 lb'. He stated that their extensive use in the aircraft industry had ensured the highest possible quality and reliability.

That much-discussed metal, beryllium, was the subject of a paper by Dr. A. J. Martin, of AWRE Aldermaston. Speaking of its properties as a structural material, he said that it is a serious contender with titanium because of its lighter weight, better heat conductivity and a considerably higher rigidity to weight ratio. 'The ductility, however, varies according to its metallurgical condition: under certain conditions it behaves with little or no ductility. This characteristic could seriously restrict its potential applications'. Other disadvantages were cost, toxicity and room temperature brittleness.

Ceramics and plastics to marry ?

Among the materials which have certain outstanding features in properties and cost that could justify considerably wider use in the future than hitherto are reinforced plastics. Mr. A. W. Thompson of Bristol Aircraft Ltd. outlined some of the features common to most varieties of these materials: they have a low density with a specific gravity range of 1·2–1·9, which is only two-thirds of the corresponding figure for aluminium and less than one-quarter of that for steel. All have a high degree of resistance to weathering and to chemical attack from a range of fluids that attack metals. They are extremely good insulators of heat and electricity and they are strong for their weight, the range of ultimate tensile strength available being from 10,000 to 140,000 lb/in². 'They are most sensitive to temperatures however', he added, 'and properties such as strength and stiffness fall off rapidly above the critical figure for the resin system in use ranging from 40°C for the cheapest polyesters, up to 180°C for special polyesters, and 300°C for special epoxides and phenolics.'

As far as heat-resistant plastics were concerned, Dr. V. E. Yarsley, of Yarsley Research Laboratories Ltd., said 'resistance to heat has always been the Achilles heel of plastics but the aim is to produce high temperature-resistant plastics'. After examining the current trends of suitable plastics materials and the requirements of the engineering industry, he concluded 'Whether plastics win out over ceramics will depend upon the vigour with which development effort is pushed in each area. There is a realistic potential evident in both fields, but the greatest potential appears to lie in merging the two approaches into some form of tough ceramic-fibre wound-roving type of reinforced inorganic laminate structure'.



Industry prefers SIMPLIFIX the foolproof coupling

Simplifix—the sure and simple compression coupling for copper pipe. Perfect joints with almost all kinds of tubing, including those with very thin walls.
No work to do on the pipe. Simply tighten the nut —the anti-friction washer prevents pipe twisting.
Manufactured since 1930, still the best. Millions in use.
Made in sizes to suit tubing from $\frac{1}{8}$" to 2" O.D., in a wide range of interchangeable standard fittings.
Non-standard fittings also made to order.
Let us send you the Simplifix catalogue.

The illustrations show control panels and centrifugal machines at the Plaistow Wharf Sugar Refinery of Tate and Lyle Ltd., where large numbers of Simplifix couplings are used.

SIMPLIFIX

SIMPLIFIX COUPLINGS LTD · HARGRAVE ROAD
MAIDENHEAD · BERKS · TEL: MAIDENHEAD 5100
A member of the ALENCO Group of Companies

Tick **No 110** on reply card for further details

People

by John Radford

Sir ERIC HARRISON The EARL of HOME T. H. A. LLEWELLYN
all together at Taylor, Taylor and Hobson's

I learn from the GEC that following **Mr R. N. Millar's** appointment as Managing Director of the Engineering Group there will be some changes at the Company's Engineering Works at Erith. **Dr K. J. Wootton** is to become General Manager of the Erith Works with **Mr C. Garrard,** previously in charge of engineering sales in Southern England, as his deputy. **Dr H. K. Cameron** moves over from the Wembley Research Laboratories—where he managed the Chemistry and Engineering Division—to take Dr Wootton's

C. GARRARD

Dr. K. J. WOOTTON

Dr. H. K. CAMERON

New moves at the GEC

place as General Manager of the Atomic Energy Division. The appointments are all effective from April 1.

Dr Leslie Silverman, Professor of Engineering in Environmental Hygiene and Director of the Radiological Hygiene programme of the Harvard University School of Public Health, has been elected chairman of the United States Atomic Energy Commission's Advisory Committee on Reactor Safeguards.

The Advisory Committee was established in the early 1950's by the Commission and was given statutory status by Congress in 1957.

From Head Wrightson comes the news of the appointment of **Mr Peter Wrightson**, O.B.E., as Vice Chairman and Managing Director. He has been Managing Director since 1955. **Mr C. H. Soppet** has been appointed Apprentice Education and Training Officer. The appointment has been necessary because of an extension in the Company's training programme. I asked Mr Soppet whether this meant they were training nuclear engineers and he told me that 'We are not training nuclear engineers as such but cover every engineering field, in fact we have twenty-three different courses ranging right up to degree standard.'

Mr Wilfred Padley, C.M.G., O.B.E., who joined Metal Industries in 1956 has been appointed to the Board. Mr Padley will relinquish his position as Managing director of Brookhirst Igranic, MI's big electrical subsidiary, and will be succeeded in that post by **Mr A. B. Vickery**, O.B.E.

A new chief engineer has been appointed by the Wireless Telephone Co. Ltd. He is **Mr R. H. Vivian,** BSc, AMIEE, previously with Associated Industrial Consultants Ltd. following many years as development engineer with A. C. Cossor Ltd.

Mr E. M. Whitaker, who since 1958 has been Personal Assistant to Lord Chandos, is now Assistant to the Commercial Director of AEI (Woolwich) Ltd. He says that this new post involves the 'administration of the selling organisation of Woolwich products of AEI.'

Mr L. C. Richards, until recently Chief Engineer of the AEI Transformer Division at Manchester, has become Chief Engineer to Heavy Electricals Ltd., India. He is seconded to this position from AEI Overseas Ltd., to whom he has been transferred.

Heavy Electricals Ltd. is the Indian Government Company building the important heavy electrical plant manufacturing centre at Bhopal. AEI are consultants to the Indian Government on the project, which is expected eventually to have an annual output worth £37,000,000.

The photograph at the top of the page was taken on the occasion of the opening of the Taylor, Taylor & Hobson private demonstration at the Engineering Centre, Stephenson Place, Birmingham, 2. The ceremony, which coincided with the inauguration of the Birmingham Commonwealth Weeks, was performed by the Rt. Hon. **Earl of Home,** Secretary of State for Commonwealth Relations. **Sir Eric Harrison,** High Commissioner for Australia, also visited the demonstration and is seen in the photograph talking to the Earl of Home and **Mr T. H. A. Llewellyn,** Chief Executive of Taylor, Taylor & Hobson.

R. H. VIVIAN
transistor expert

E. M. WHITAKER
from Chandos to Woolwich

Dr N. Hilberry, Director of the Argonne National Laboratory, has announced that **Dr Stephen Lawroski,** Director of the Chemical Engineering Division, will serve as Coordinator of Engineering Research and Development Programmes at Lemont, Ill., atomic energy facility.

Dr Lawroski will continue to direct the activities of the Chemical Engineering Division.

Commenting on the Argonne scientist's new responsibilities, Dr Hilberry said: 'In performing these additional duties, Dr Lawroski will provide for the Laboratory increasingly needed technical and scientific leadership and coordination in the areas of engineering research and development. An important part of his assignment will be to serve as Chairman of Argonne's Reactor Engineering Steering Committee'.

nucleol

radiation resistant lubricants for the atomic age

A range developed and perfected by Wakefield-Dick Research

Conventional oils cannot live in conditions of atomic radiation. Such conditions are inseparable from certain parts of any mechanism designed to produce power from nuclear fission.

This, and other allied lubrication problems, was the challenge which faced oil technologists everywhere. And, as so often in the past, Wakefield-Dick's research team produced the answer. An entirely new series of oils and greases, resistant to radiation and named "Nucleol", is now available to lubricate the wheels of this Atomic Age.

A Wakefield-Dick research chemist investigating the effects of radiation on lubricants.

Two examples of the NUCLEOL range

NUCLEOL 522 A radiation resistant lubricant based on selected mineral oils of high aromaticity and containing special inhibitors.

NUCLEOL G 120 A grease gelled with a new compound, and specially inhibited. Designed for the lubrication of control actuator bearings operating at the lower radiation levels.

Tick **No 111** on reply card for further details

LOOKING AHEAD

MARCH 30
Design and Performance of Zeta R. Carruthers Institution of Electrical Engineers at Sheffield Sub-Centre

MARCH 30–31
Conference on Nuclear Physics Physical Society at Chadwick Laboratory, Liverpool University

APRIL 5–9
Ninth Electrical Engineers' Exhibition at Earls Court, London, SW5

APRIL 6
Modern Ferromagnetic Materials Prof. F. Brailsford Institution of Electrical Engineers at College of Technology, Portsmouth

APRIL 6–9
International Mineral Processing Congress and Exhibition at Church House, Westminster, London, SW1

APRIL 7
The Work of the B.S.I. in Relation to the Radio and Electronics Industry H. A. R. Binney British Institution of Radio Engineers 6.30 at London School of Hygiene, Keppel Street, London, WC1

APRIL 8
Nuclear Fuel Element Inspection R. S. Sharpe Institution of Physics 6.00 at 47 Belgrave Square, London, SW1

APRIL 19–22
International Symposium on the Metallurgy of Plutonium. Session on Nuclear Fuels, Société Française de Métallurgie and Commissariat à l'Énergie Atomique at Grenoble, France

APRIL 20
Welding of Stainless Steel J. A. McWilliam Institution of Production Engineers. 7.00 at Wolverhampton College of Technology

APRIL 20
Radioisotopes in Engineering W. D. Busbridge Institution of Radio Engineers 7.30 at Conference Room, Peterscourt, Peterborough

APRIL 21
Production of Thorium Metal R. A. Gibson Institution of Mining and Metallurgy 5.00 at Geological Society, Burlington House, Piccadilly, London, W1

APRIL 21–22
Training of the Industrial Physicist Symposium at Birmingham Applications to Secretary, Institute of Physics, 47 Belgrave Square, London, SW1

APRIL 23
The Production Engineer in a Changing Economy Institution of Production Engineers One-day conference at Rolls Royce, Derby

APRIL 25–29
International Compressed Air and Hydraulics Exhibition Empire Hall, Olympia, London

APRIL 25–29
Seminar on Codes for Reactor Computations at IAEA, 11 Kärntner Ring, Vienna

APRIL 25–29
Sixty-seventh Annual Health Congress of the Royal Society of Health at Torquay

APRIL 25–30
Fourth Production Exhibition at the National Hall, Olympia, London, W14

APRIL 26
Some Recent Advances in Industrial Electrical Control Techniques T. E. Barany The Society of Instrument Technology 7.00 at Manson House, 26 Portland Place, London, W1

APRIL 26
Sealing against pressure and vacuum Joint meeting of the Institution of Chemical Engineers and the Institute of Petroleum at Manchester

APRIL 27–29
Second European Symposium on Chemical Reaction Engineering—Section on non-conventional reactors Amsterdam Enquiries to P. J. Hoftyzer, Centraal Laboratorium Staatsmijnen, Geleen (L.)

APRIL 27—MAY 6
Fuel Efficiency Exhibition Grand Hall, Olympia, London

APRIL 29
Some Aspects of Ionizing Radiation in Medicine Dr. R. Morgan Institute of Physics 5.15 at University College of Wales, Aberystwyth

APRIL 29
Application of Semi-conductor Devices in Power Supplies D. D. Jones British Institution of Radio Engineers 7.00 at North Gloucestershire Technical College, Cheltenham

APRIL 29–30
Convention on Thermonuclear Processes. The Institution of Electrical Engineers at Savoy Place, London, WC2

MAY 2–3
Second Conference on Reactions between Complex Nuclei American Physical Society

MAY 2–3
Selection of Fuel-using Equipment and Power Plant Series of technical meetings at Fuel Efficiency Exhibition Details from The Institute of Fuel, 18 Devonshire Street, London, W1

MAY 2–4
Non-destructive Testing Joint meeting of the Société Française de Métallurgie and the Non-destructive Testing Group, The Institute of Physics at 47 Belgrave Sq., London, SW1

MAY 3–13
Mechanical Handling Convention and Exhibition at Earls Court, London, SW5

MAY 4–6
International Symposium on Distillation. Joint meeting of the Institution of Chemical Engineers and the Society of Chemical Industry, sponsored by the European Federation of Chemical Engineering, at the Dome, Brighton

MAY 4–6
Annual Conference of Institution of Plant Engineers Papers on 'Welding problems and development' by Dr. R. Week and 'Developments in Materials' by K. S. London

MAY 5
Direct Conversion—Its Physics and Applications Donald H. Loughridge of GM Research Laboratories at Northwestern University, Evanston, Illinois, USA

MAY 10–13
IAEA Fuel Element Fabrication Symposium Vienna Special emphasis on cladding materials

LOOKING FURTHER AHEAD

MAY 23–28
Instruments, electronics and automation exhibition, London

JUNE 5–9
Sectional Meeting of the World Power Conference in Madrid. Applications to the Secretary, British National Committee, World Power Conference, 201–2 Grand Bldgs., Trafalgar Sq., London, WC2

JUNE 13–29
Seventh International Nuclear Congress and Exhibition on Electronics and Atomic Energy National Committee for Nuclear Research at Rome, Italy

JULY 18–26
Royal Society tercentenary celebrations

JULY 20
The Study of Nuclear Interactions at very great Energies Prof. C. F. Powell Royal Society 2.30 at Beveridge Hall, London University

JULY 21
National Institute for Research in Nuclear Science, Harwell Royal Society visit leaves Burlington House at 2.30 Accommodation for 50 persons Another visit on July 26

JULY 21–30
International Nuclear Power Exhibition at Earls Court, London, SW5

CATALOGUES AND BULLETINS

Electronic equipment. The 24th edition of 'The Radio-Electronic Master' contains over 1500 pages of classified parts and equipment sold by US distributors in the fields of radio, television and electronics. Descriptions, specifications, illustrations and prices are given of each item.
Tick **No 254** on reply card

Nucleonic instruments. A wide range of specifications for nuclear equipment is covered in the latest catalogue from Terminal Radio and includes phototubes, scintillators and radiation monitors.
Tick **No 255** on reply card

Accelerometers to vacuum gauges. A new publication from Smiths surveys the principal fields of its activities and research and technological training.
Tick **No 256** on reply card

Trace techniques. The K1000 cathode ray polarograph has made a useful contribution in extending the use of polarography in analytical chemistry. A new publication from Southern Instruments contains 30 original polarographic determinations not previously carried out using this technique, setting out in each case details of sample preparation, basic electrolyte, determination and interpretation.
Tick **No 257** on reply card

Silicone fluids. A leaflet from Midland Silicones outlines the properties of these fluids useful for engineering applications.
Tick **No 258** on reply card

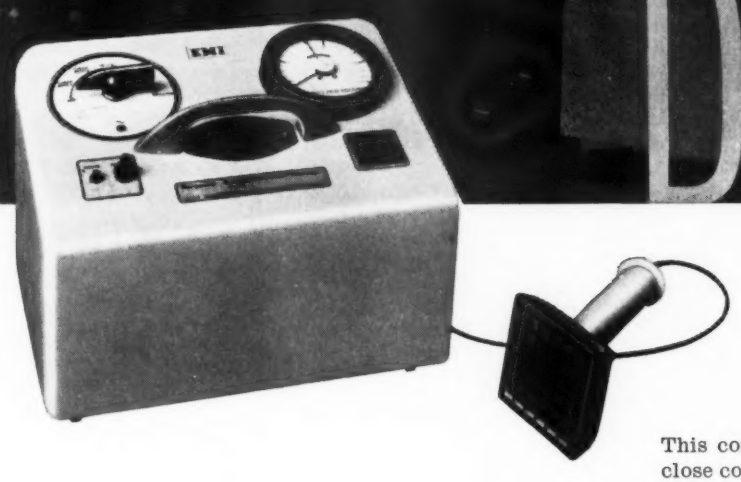
Improved material utilization. To assist in the reduction of production costs, the Institution of Production Engineers have issued recommendations on the use of raw and process materials covering finishing, packaging, ceramics, metal powders and plastics.
Tick **No. 259** on reply card

Tubend welding fittings. The latest BKL Alloys' catalogue gives specifications of all their elbows, return bends, equal tees, concentric and eccentric reducers and caps. Tables are included giving comparisons between British and American standards for various materials.
Tick **No 260** on reply card

Motors for many uses. The latest issue of 'Drayton News' describes the RQ range of fractional horsepower motors that provide 300 different speeds.
Tick **No 261** on reply card

Alpha Beta

A new portable contamination monitor



E.M.I. PORTABLE MONITOR TYPE 1

This compact instrument, developed in close collaboration with the U.K.A.E.A., has resulted from a successful combination of all-transistor circuitry with the E.M.I. dual phosphor technique. It represents a significant advance in the detection of Alpha-Beta contamination. Its most outstanding features are:

- ✳ *Simultaneous monitoring of Alpha-Beta radiation, giving aural and visual warnings.*
- ✳ *Transistors throughout for reliability, lower power consumption and long life.*
- ✳ *Battery operation for real portability.*
- ✳ *High accuracy over wide temperature range.*
- ✳ *Mains unit available if required.*

EMI

Ask for a demonstration and full details.

E.M.I. ELECTRONICS LTD

INSTRUMENT DIVISION · HAYES · MIDDLESEX · TELEPHONE: SOUTHALL 2468

EE.77

Tick **No 112** on reply card for further details

Tick **No 262** on reply card

For the first time— a GIANT new reference work

Over 1,400 pages

Over 14,000 entries

Over 1,400 illustrations

Over one million words

Encyclopedic Dictionary of ELECTRONICS & NUCLEAR ENGINEERING

by Robert I. Sarbacher

You cannot hope to remain completely up to date without this inexhaustible compilation of modern terms and definitions, equipment, elements, components and systems. A quick-look-up and you know your answer, definitely and authoritatively. No wonder this giant alphabetical work, presented after twelve years preparation, has established itself as the one essential book for all engineers, physicists and scientists.

£8 net

easy payment plan

The Modern Book Co., 19-23 Praed St., London, W.2, has arranged a special instalment plan to cover payment of the book over one year.

Write to them for a special Order Form.

from all booksellers

PITMAN

Parker St

Kingsway

London WC2

Book Reviews

Reactor technology

Physique Nucléaire Appliquée by R. Guillien Paris 1960: Editions Eyrolles 663 pp Price NF85

This account of applied nuclear physics is intended for students taking the Higher Certificate in Nuclear Physics and for electrical engineers entering the nuclear industry. It is impossible to cover all the aspects of such a wide field in one volume and, naturally, there are many gaps. The subject of heat removal is a particular example, but satisfactory treatment would have made the text unwieldy. Mathematical discussion is included whenever it has been considered necessary for precision and clarity.

After examining the nature of matter and radiation, with a limited use of quantum mechanics, the author explains the operation and application of mass spectrographs. He then reviews the various procedures for particle detection and the function of large particle accelerators. The most detailed section commences with an account of radioactive phenomena and induced nuclear transformation, introduces briefly the various types of reactor and follows with an outline of reactor technology. Reactor theory is given in such a way as to permit reactor calculations to be made. Other chapters cover reactor control, radiation protection and the various applications of radio-isotopes and radiations.

Introduction au Génie Nucléaire, 3 volumes edited by T. Reis Paris 1957–1959: Eyrolles Price NF107

This series of volumes on reactor technology has been written at a relatively elementary level but they are now regarded as standard works in France. They were prepared as an introduction to the subject by scientists and engineers engaged at the research centres of Saclay or Grenoble or in charge of project work in industry. Volume 1 'Physics and mathematics of nuclear reactors', covers nuclear reactions, neutron physics, reactor theory and kinetics and includes calculations for different types of reactor. Volume 2 'Control and protection', explains the detection of particles and ionizing radiation and the use of ionization chambers, proportional, geiger-müller and scintillation counters. The problems of reactor control are examined, and an explanation of the nature and need for physical and biological shielding is given. Volume 3 'Removal and recovery of heat', forms an introduction to the thermal problems in nuclear reactors and, after examining the fundamental laws of heat transfer, all types of coolants normally used for reactor cooling are described. An account of thermodynamic cycles includes a discussion of gas-turbine cycles and the choice of parameters. An example is given of a particular gas-turbine power station. The book concludes with short but concise descriptions of thermal circuits of the various reactors.

Technologie des Réacteurs Nucléaires, volume 1: Matériaux by P. Ageron et alia Paris Eyrolles et Gauthier-Villars 1959 568 pp Price NF69

The first volume of a new series on reactor technology covers such materials as fuel, reflectors, moderators, coolants, neutron absorbers, shielding and constructional materials. A great amount of experience has been gained by French research workers and industrial engineers on the recovery of uranium, particularly from very low grade ores; they have treated irradiated fuels

Tick **No 263** on reply card

NEW BOOKS

on Atomic and Nuclear Physics

(General, Advanced and Applied) Supplied from stock. Foreign books not in stock obtained to order. Catalogues on request.

SECOND-HAND BOOKS

A constantly changing large stock of Scientific and Technical Literature on view, classified under subjects.

LENDING LIBRARY

Technical and Scientific

Annual Subscription from £1 . 17 . 6. Bi-monthly list of New Books and New Editions sent post free to all subscribers on request. Prospectus post free on application.

H. K. LEWIS & CO. LTD

136 Gower St. W.C.1. EUS 4282

and have handled plutonium. The chapters on these subjects, therefore, are particularly good because they are based on the personal experience of the authors. Other materials are more in the nature of reviews of current knowledge.

Radiation detection

Rayonnements de Particules Atomiques, Electrons et Photons by A. Berthelot Paris 1959: Masson 192 pp Price NF23·50

This book is based on a course given over many years at the Faculty of Sciences in Paris for students preparing for the licence certificate in 'Nuclear physics and radioactivity'. After an account of current ideas concerning the properties of radiation, the case of fission particles in movement is considered at length including the more complex interactions of electrons and photons and the loss of energy.

Détecteurs de Particules (compteurs et scintillateurs): Mécanisme et Réalisation by Daniel Blanc Paris 1959: Masson 324 pp Price NF39

This is the first comprehensive treatise on this subject in the French language and it is based on the lecture courses given by the author to students in advanced studies on nuclear physics at the University of Toulouse. Whilst it follows in many parts the same lines as similar books published in Great Britain or in USA, it provides a more comprehensive view and precise description of geiger counters with glass walls, halogen counters and pure vapour counters as well as spark and electric conduction detectors. Stress is given to the construction of detectors and scintillators.

Gases and solids

Physique Electronique des Gaz et des Solides by Michel Bayet Paris 1958: Masson 246 pp Price NF52

The properties of electrons in matter and the resultant macroscopic phenomena are presented for theorists interested in the possible developments of certain difficult aspects of the kinetic theory of gases. The book is also intended for engineers and technicians who may require a complete survey and guide to the many practical problems, the interpretation of which are often obscure.

The author has given no consideration to electron properties in liquids because of the uncertain state of knowledge. He has related the physics of solids and gases, treatment of which is normally separated, with the justification that it is generally impossible to study gas properties without relating them to those of solids. Furthermore, the phenomena of transfer is studied by means of the same equation, that of Boltzmann applied to a Lorentzian gas. The first part of the book is essentially theoretical, with pure mathematical development referred to in an appendix. After giving an account of fundamental aspects in statistical and particle physics, a survey follows of the essential results of the kinetic theory of gases formed of one or more particular kinds. The second part is devoted to the study of the phenomena of electric currents in gases and solids, giving only the essentials without entering too much into technical details, already the subject of many publications. The author limits discussion to certain results, proven or of general significance.

Quantum mechanics

Mécanique Cantique, volume 2 by Albert Messiah Paris 1960: Dunod 974 pp Price NF48

Although not directly concerned with nuclear engineering, this book is valuable to students making a more detailed study of nuclear science. Quantum mechanics has been written about with considerable precision and clarity and, although this second volume uses advanced mathematics, the theories of tensors and of groups are set out in two very readable annexes. It is to be hoped that a book that is already becoming a standard work will be made available in other languages.

MASSON & C^IE *French Publications in the Field of Nuclear Power*

DÉTECTEURS DE PARTICULES
COMPTEURS ET SCINTILLATEURS
MÉCANISME ET RÉALISATION
par D. BLANC
Un volume de 324 pages, avec 126 figures et 33 tableaux.
3 900 F (39 NF)

NOUVEAU TRAITÉ DE CHIMIE MINÉRALE
publié sous la direction de P. Pascal
TOME XV
URANIUM ET TRANSURANIENS
avec la collaboration des
Ingénieurs du Commissariat à l'Énergie Atomique
2 fascicules de 1 200 p. chacun environ. **(sous presse)**

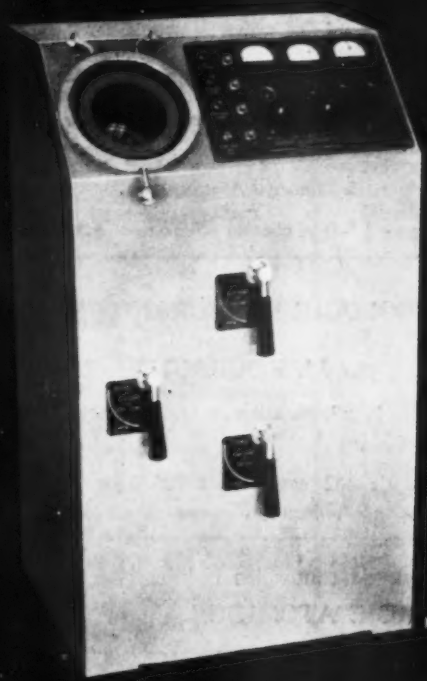
RAYONNEMENTS DE PARTICULES ATOMIQUES, ÉLECTRONS ET PHOTONS
par A. BERTHELOT
Un volume de 192 pages, avec 101 figures.
2 350 F (23,5 NF)

GÉOLOGIE DE L'URANIUM
par M. ROUBAULT
avec la collaboration de G. JURAIN
Un volume de 462 pages, avec 205 figures et cartes, 2 planches et 9 tableaux. **6 000 F (60 NF)**

MM. MASSON & Cie sont dépositaires pour la France de toutes les publications de l'AGENCE EUROPÉENNE DE L'ÉNERGIE ATOMIQUE.

CATALOGUES ET DOCUMENTATION ENVOYES SUR DEMANDE A MASSON & CIE, 120 BOULEVARD SAINT-GERMAIN, PARIS-VI

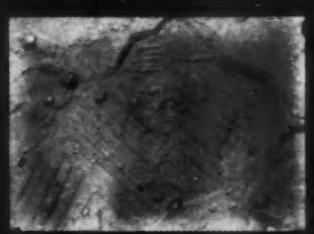
CATHODIC VACUUM ETCHER **a metallurgical must** for advanced materials development and production filling today's pressing needs for more precise interpretations of material structure · ADVANCED—produces high resolution of microstructure previously unattainable through standard techniques · UNIQUE—enables easy, simultaneous preparation of dissimilar materials not readily etched by conventional chemical or electrochemical techniques such as roll-bonded uranium, zirconium, niobium, hafnium, nitride-coated and cobalt stainless steels · DEPENDABLE—Uniform, reproducible results in less time with a minimum of effort. Eliminates the guesswork · RUGGED—simple construction, thoroughly tested, designed for day-in, day-out trouble-free operation



Model 4 CVE

NUMEC

nuclear materials and equipment corporation



304 Stainless Steel; original 500x

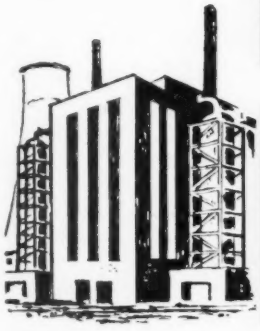
apollo, pennsylvania

cable NUMEC ·

telephone GRover 2-8411

GRAPHITE MACHINING

Powell Duffryn Carbon Products Ltd.
are the official contractors
to the General Electric Company
for the machining of Nuclear Graphite.



THE POWELL DUFFRYN GROUP OF COMPANIES

POWELL DUFFRYN CARBON PRODUCTS LTD.,
NUCLEAR GRAPHITE DIVISION
Springfield Road, Hayes, Middlesex. Telephone Hayes 3994

Tick **No 115** on reply card for further details

TNPG

A partnership has been established between The Nuclear Power Plant Company Limited and AEI—John Thompson Nuclear Energy Company Limited to design and construct better and cheaper nuclear power stations

This new enterprise is called

The Nuclear Power Group

and combines the research development, manufacturing and construction resources of these industrial concerns of world-wide renown.

ASSOCIATED ELECTRICAL INDUSTRIES LIMITED

CLARKE, CHAPMAN AND COMPANY LIMITED

ALEX. FINDLAY AND COMPANY LIMITED

HEAD, WRIGHTSON AND COMPANY LIMITED

SIR ROBERT McALPINE AND SONS LIMITED

C. A. PARSONS AND COMPANY LIMITED

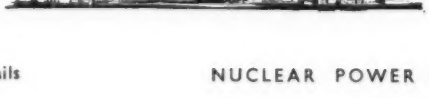
A. REYROLLE AND COMPANY LIMITED

STRACHAN AND HENSHAW LIMITED

JOHN THOMPSON LIMITED

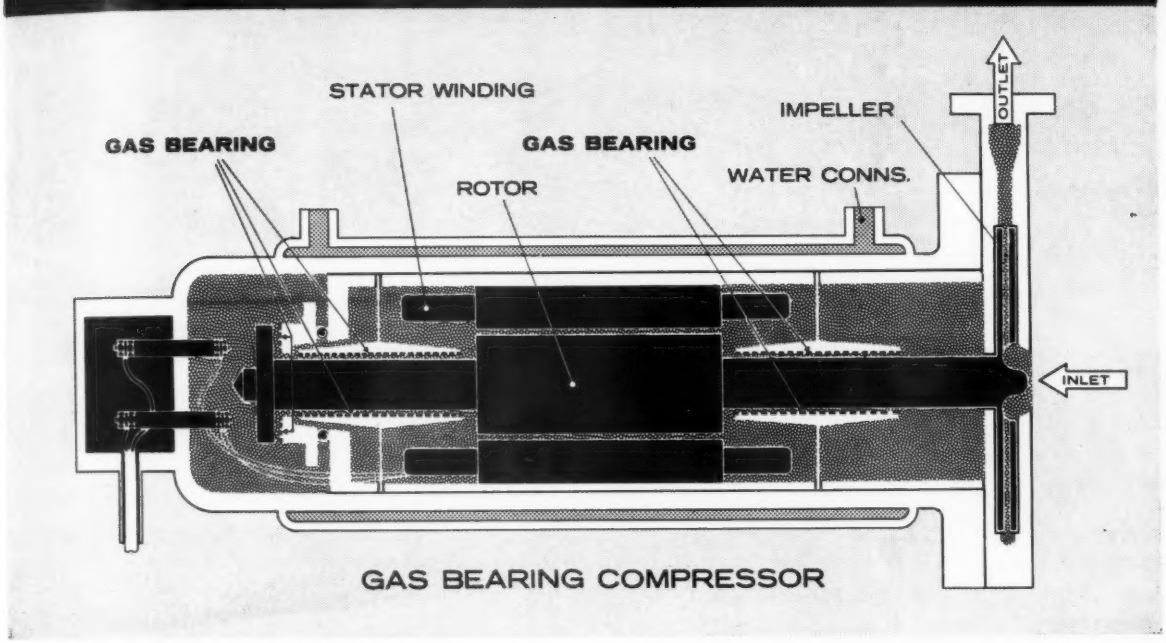
WHESSOE LIMITED

RADBROKE HALL · KNUTSFORD · CHESHIRE



TGA NP 158

Gas bearing compressors – totally enclosed, lubricant free – circulate gases up to 700°C, 2,000 psi, without contamination . . .



GAS BEARING COMPRESSOR

...ANOTHER ENGINEERING ADVANCE BY BRISTOL SIDDELEY

One of the largest manufacturers of motive power units in the world, Bristol Siddeley Engines Limited produce gas bearing compressors. The range covers a very wide performance capacity, from 0°—700°C gas operating temperature, 15—2,000 psi and 0.5—2,000 hp power input.

These Bristol Siddeley compressors have been designed specifically for systems where contamination from lubricants or leakage to atmosphere cannot be tolerated. Each unit, fitted with hydrodynamic-type gas bearings, is totally enclosed and no seals are required between the impeller and the bearings.

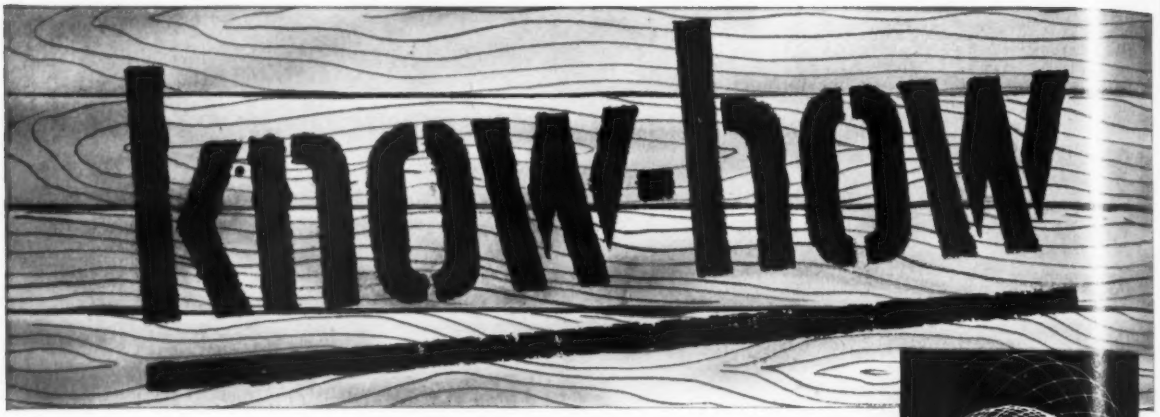
Gas bearings have several great advantages over oil lubricated bearings: the load-carrying capacity increases with speed, temperature and pressure; the bearings are supported on a film of the gas which is being circulated in the system, so there is no metal-to-metal contact under operating conditions and wear and maintenance are reduced to an absolute minimum; perfect cleanliness is preserved at all times.

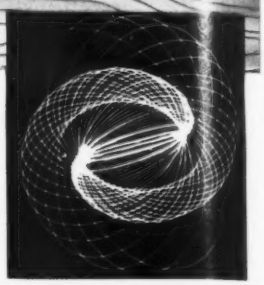
Applications

Bristol Siddeley gas bearings were developed originally to meet the extremely fine limits of operating purity and precision of manufacture demanded by the advent of nuclear engineering. But gas bearings have many other applications where a rotating shaft must be supported in such a way that no contamination and leakage can be allowed and where the supply of chemically pure fluids or gases is essential: in the textile, chemical engineering, pharmaceutical, food storage and processing industries, to name but a few.

For further information about Bristol Siddeley gas bearing compressors and gas bearings, please write to H. J. Prince, Sales Manager, Reactor Components Division, Bristol Siddeley Engines Limited, P.O. Box 17, Coventry, England.

BRISTOL SIDDELEY ENGINES LIMITED





— the Stamp of experience which is on all Atomic Energy Equipment manufactured by Graviner. We can make almost anything in this rather new sphere of activity, whether it be a lead-filled shielded container, a Thulium storage magazine, a magnet for neutron beam focusing or a 20 ton mobile cell unit with viewing windows and handling equipment. We specialise too, in the machining of graphite. Indeed, with the recent addition of 12,500 square feet of factory space we can deal with anything from the making of a tiny graphite spring to a Reflector for a Reactor — all under controlled clean conditions. If therefore you have a Development or Production problem, our Nucle. r Energy Division will be very pleased to help you. Won't you pay a visit to the Gosport Factory and see what we can do?

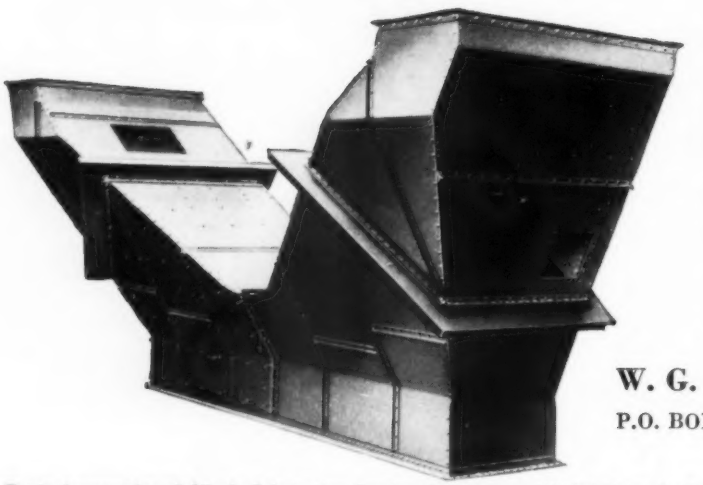
GRAVINER

Contractors to The Atomic Energy Authority

FAREHAM ROAD · GOSPORT · HANTS · Telephone Fareham 2511

Also specialists in Airborne, Diesel Engine and Industrial Fire and Explosion Protection, Thermostats and Overheat Switches

Fabricated Platework to your specification



We specialise in welded or riveted fabrications in Mild Steel, Stainless Steel and Aluminium Alloys and pride ourselves on the attention paid to constructional details which ensure trouble-free service for the finished product.

A typical example of our craftsmanship is the fabrication of Ducts of rectangular design for Power Stations or Boiler Houses. They are accurately fabricated to suit your requirements.

Our "FABRICATED PLATEWORK" Brochure fully describes our Service and is available on application.

W. G. ALLEN & SONS (TIPTON) LTD.

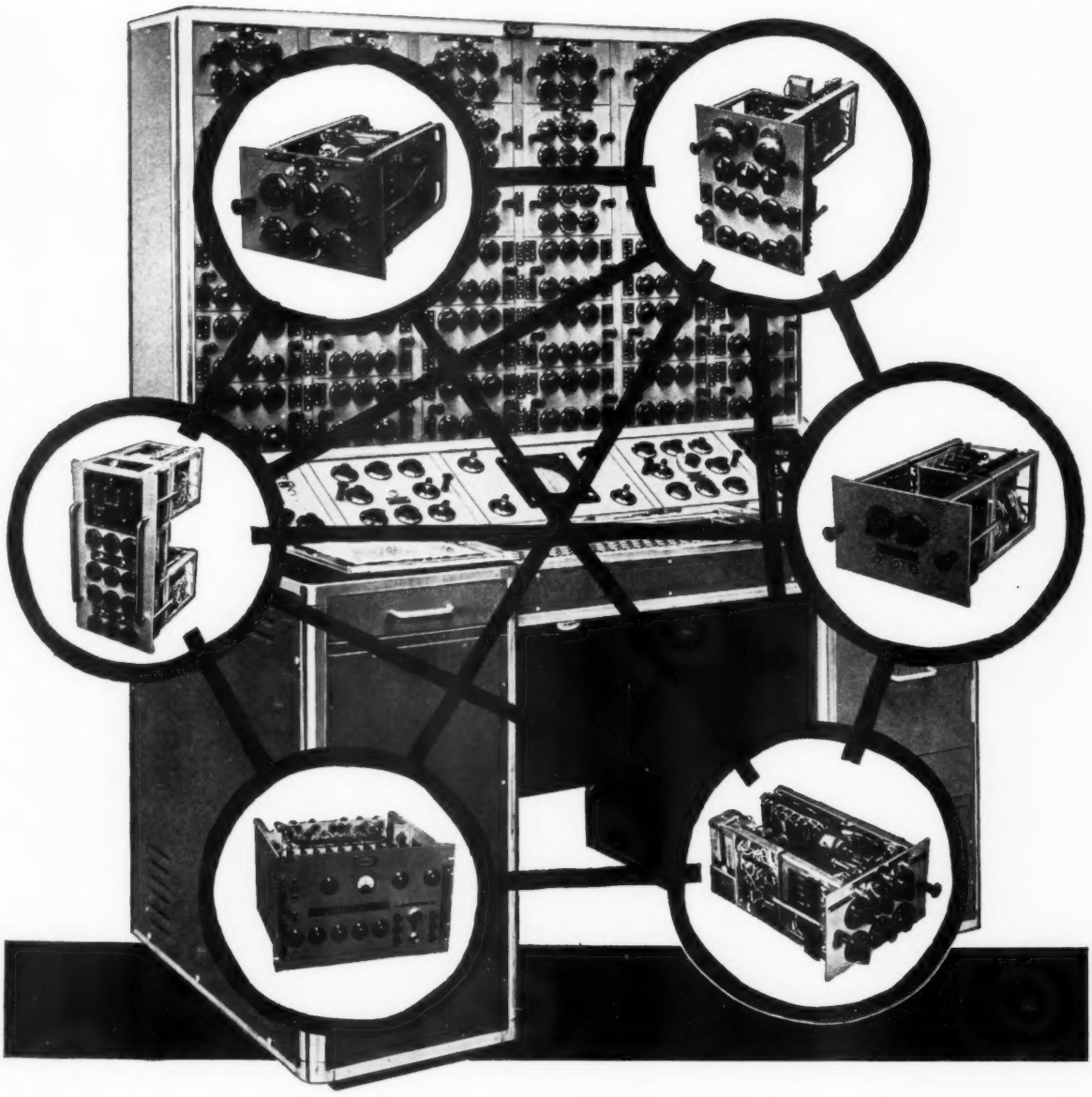
P.O. BOX 4 · TIPTON · STAFFS

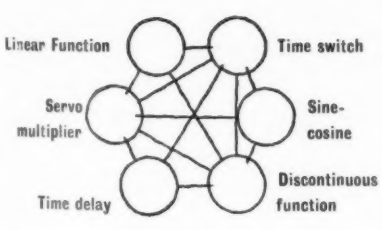
Tel: TIPTON 1266

Typical examples of Allen's Fabrication Service: *Low Pressure Welded Piping for Exhaust Steam, Gases, Water, etc. Pipes and Ducts for Super Power Station Boiler Plant; Hoppers; Casings; Tanks; Flat Platework; Manipulated Platework of all kinds; Bed Plates and Frames for Machines, etc.*

Shorts General Purpose Analogue Computor

The computor with the widest range of units



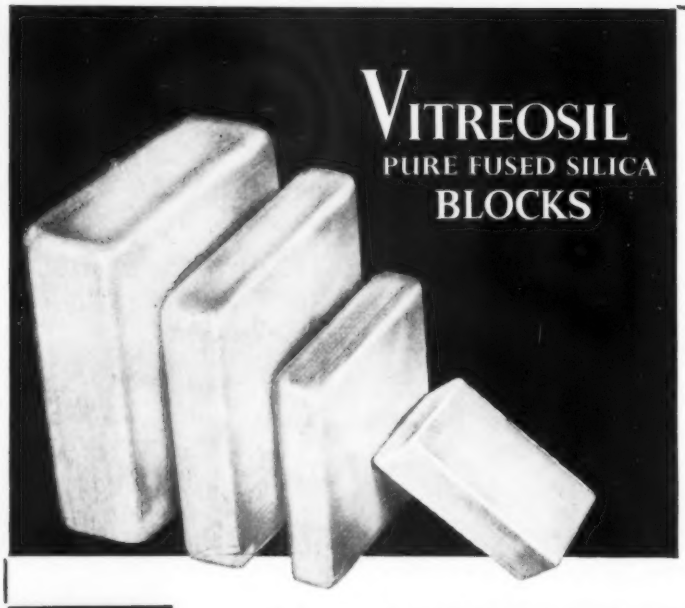


- In service throughout the world
- Patching without cords
- Fast repetitive or continuous solution
- Switch set coefficients and transfer functions
- Units quickly interchangeable
- Display, power supplies, and timing contained within console

Write for illustrated brochure and data sheets to: **COMPUTOR SALES DEPARTMENT, SHORT BROTHERS AND HARLAND LIMITED**

East India House, 208a Regent Street, London, W.1

Tick **No 120** on reply card for further details



VITREOSIL
PURE FUSED SILICA
BLOCKS

Vitreosil Pure Fused Silica Blocks are now available up to 36″ × 18″ × 18″; larger sizes are under development.

Present applications are for special glass melting furnaces and constructions where freedom from contamination and stability at high temperatures are desired.

Your enquiries will be given prompt attention.

TSL
SERVICE TO SCIENCE

THE THERMAL SYNDICATE LTD.

P.O. Box No. 6 WALLSEND, NORTHUMBERLAND. *Tel: Wallsend 62-3242*

LONDON : 9 BERKELEY STREET, W.1. *Tel: Hyde Park 1711/2*

ROLLED STEEL RINGS

IN CARBON AND ALLOY STEELS

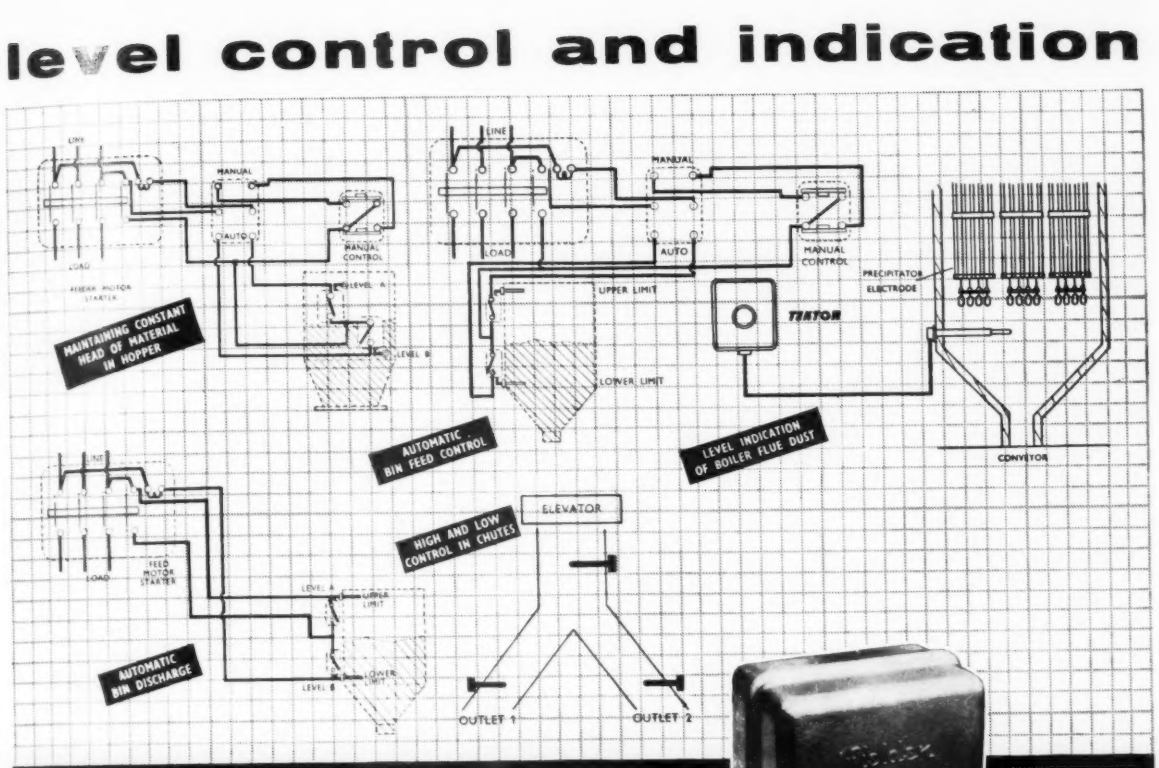
Leaflet giving full details of manufacturing capacity available on request

JOHN BAKER & BESSEMER LIMITED

Kilnhurst Steel Works G.P.O. Box No. 3 Rotherham Yorkshire Phone: Mexboro' 2154/7 & 3793 Telegrams: Tyres Mexboro'

London Office
Locomotive House, Buckingham Gate, London S.W.1. Telephone: Victoria 5278

level control and indication



by the Fielden CAPACITANCE METHOD

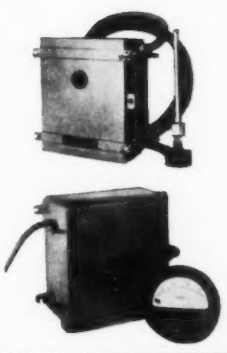
The principle of capacitance control and indication of level for industrial purposes has been successfully used by Fielden Electronics Ltd. for the past ten years. In that time it has produced a range of instruments used throughout the world to answer almost every level problem involving any liquid or free-flowing solid regardless of conductivity, insulating value, density or corrosive properties. Installation is simple, there are no moving parts in the container and direct contact with the material is unnecessary.

Send for fully illustrated leaflet GL1/NP

The range includes the famous

TEKTOR REGD. LEVEL CONTROLLER

TELSTOR REGD. LEVEL INDICATOR



solids or fluids their levels can be accurately measured by the Fielden method

Fielden

FIELDEN ELECTRONICS LTD · WYTHENSHAWE · MANCHESTER Phone: Wythenshawe 3251 (4 lines) Grams: Humidity Manchester
ALSO AUSTRALIA, ITALY AND CANADA *Branch Offices:* LONDON, WALSALL, STOCKTON-ON-TEES, EDINBURGH AND DUBLIN.
Agents throughout the world
TT3

Indicating Recording Control

Tick **No 123** on reply card for further details

Tick **No 124** on reply card for further details

18/8 Titanium *(LOW COBALT)* Stainless Steel Wire

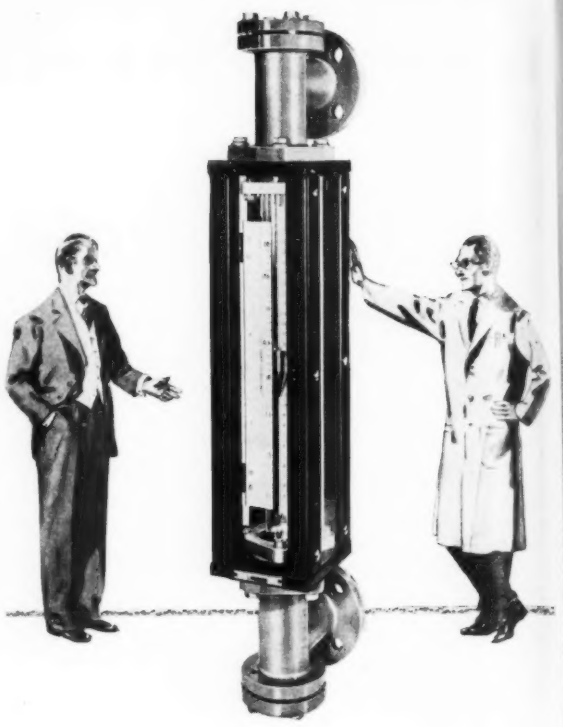
Stainless Steel Wire, to this specification, is already being supplied by us in ever increasing quantities to meet the specific requirements of Nuclear Engineers and Designers. We shall welcome your enquiries for this and all other types of Austenitic Stainless Steel Wire.

Stainless Steel Wire Company Limited

THE BARRACKS · LANGSETT RD
SHEFFIELD 6

Telephone No.: 344241-2 Sheffield
Telegrams: Finewyre · Sheffield

Tick **No 125** on reply card for further details



"but why a metric Rotameter?"

Because it is a low cost high quality flowmeter that can be delivered from stock, can be adapted to meter different fluids, can be serviced from interchangeable stock parts, and which has a mounting designed to withstand rough industrial service.

Metric Rotameters comprise sixteen sizes of tube accommodated in five sizes of frame to cover flows up to 200 Litres/Minute of water or 2,000 Litres/Minute of air at N.T.P. Interchangeable floats of differing composition cater for all gases and liquids including corrosives. P.T.F.E. gland packings are available.

Full information is given in leaflet NP.2020/27.

ROTAMETER
FLUID MEASUREMENT AND CONTROL
FLOW-DENSITY-LEVEL

IEA EXHIBITION
STAND No. E210

ROTAMETER MANUFACTURING CO. LIMITED
330 PURLEY WAY · CROYDON · SURREY
Telephone: CROydon 3816

M.27

INCINERATORS
ACTIVE WASTE

The H.W.P. plant at Harwell reduces all dry combustible radio-active waste to a small volume of ash for economical disposal; off-gases being scrubbed and filtered to remove active particulate matter. It is designed to minimise blow-back thus protecting operators from dust-borne radiation hazards. Waste materials are fed from a dry-box into a gravity feed hopper which has a trap to prevent blow-back into the dry-box.

THE WIDE FACILITIES
AND EXPERIENCE OF
HEAD WRIGHTSON PROCESSES LTD.
ARE BEING CURRENTLY APPLIED
TO THE DESIGN
AND CONSTRUCTION OF SIX
LARGE NUCLEAR RESEARCH REACTORS
AND MUCH ANCILLARY
EQUIPMENT—THUS PROVIDING

A COMPLETE ENGINEERING SERVICE FOR NUCLEAR DEVELOPMENT

ACTIVE MATERIAL HANDLING FLASKS

This stainless steel flask—one of many supplied for DIDO—has a 12" lead wall and is used for extracting irradiated fuel elements from the reactor and transferring them to storage. A self-contained cooling circuit is built into the flask to maintain the fuel elements at a safe temperature throughout all operations.

HEAD WRIGHTSON PROCESSES LTD

London and Sales Office: 20/24 OLD STREET LONDON EC1

Head Office: The Friarage · Yarm · Yorks

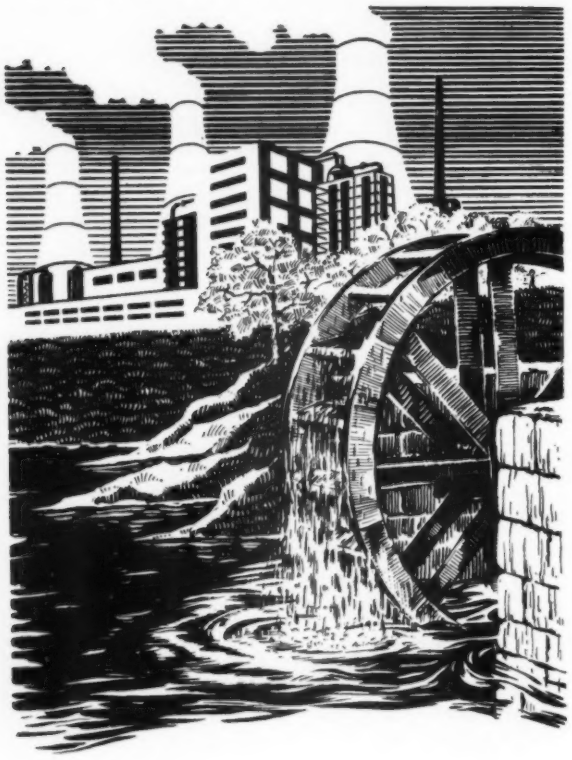
Offices at P.O. BOX 1595 SYDNEY **P.O. BOX 1034 JOHANNESBURG** **P.O. BOX 2608 CALCUTTA** **P.O. BOX 706 HAMBURG**

Associates in the U.S.A., The Fluor Products Co., Los Angeles, New York, Chicago, etc.

P922

Tick **No 126** on reply card for further details

Tick **No 127** on reply card for further details



WATER

is still in the foreground...

However revolutionary the methods of producing power may become, water is still all-important; and the need to give complete and lasting internal protection to water tanks in modern plants remains paramount.

With a reputation consolidated over 30 years of successful use

BITOTES Solution and Enamel

prevents interior corrosion of all steel and concrete water containers and conduits. BITOTES cannot crack or peel and is tasteless and odourless when dry. It is fully approved for Fresh Water, Drinking Water, Demineralised Water, etc.

May we send you details

BITULAC LIMITED

(PAINTS DIVISION)

Collingwood Buildings, Newcastle upon Tyne, 1.

London Office: 189/190 Temple Chambers, Temple Avenue, London, E.C.4

Tick **No 128** on reply card for further details

OLYMPIA LONDON

June 25 - July 8

(Sundays excepted)

9.30 am - 6 pm

Make sure you visit the greatest engineering event of the year—The International Machine Tool Exhibition . . . No-one concerned with quantity production—whether in technical, administrative or operative capacity—can afford to miss this vast and truly comprehensive show at Olympia, London. It summarizes the best of contemporary production techniques; it shows the shape of things to come!

Machine Tools
Engineers' Small Tools
Gauges and Measuring Equipment
Testing Equipment
Electronic Control Gear
Presses and Power Hammers
Woodworking Machinery
Heat Treatment Plant

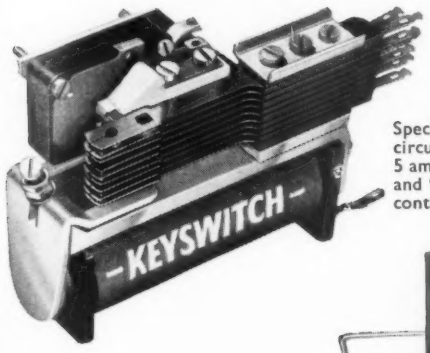
Here's your opportunity to see them all under a single roof—to see many of them powered and in operation—to discuss their application to your own production problems with the world's best-informed production experts.

International Machine Tool Exhibition 1960

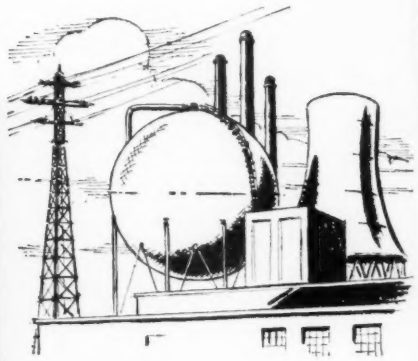
Organized by The Machine Tool Trades Association, Brettenham House, Lancaster Place, London, W.C.2.

MEN IN THE KNOW
HAVE THE RIGHT CONTACTS

Versatile and reliable, Keyswitch relays set the standard for design robustness, sensitivity and extremely efficient operation—even under the most hazardous operating conditions.



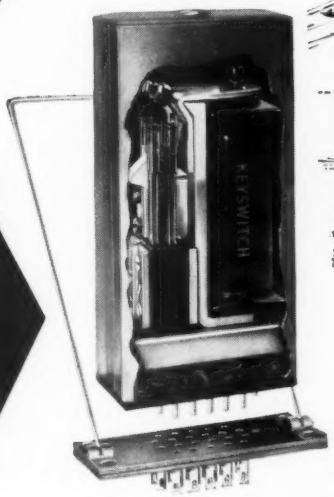
Special combined relay circuits fitted with 5 amps. micro switch and 9 standard 0.3 amp. contacts.



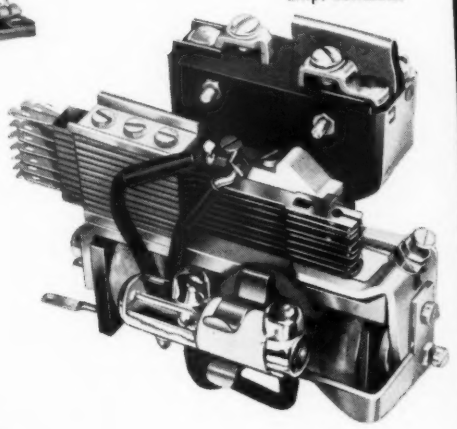
and now Plug-in 3,000 Type Relay

All the versatility and well established abilities of the best known relays in the world plus plug-in facilities.

- ★ *Positive contact between male and female pins.*
- ★ *Transparent or metal cover.*
- ★ *Clip retains relay positively in any position.*
- ★ *Contacts up to 18 light duty or 12 heavy duty.*
- ★ *Complete transistorized or A.C. units.*



This relay incorporates 15 amp. Micro Switch, 5 amp. Mercury Switch and Standard 0.3 to 8 amp. contacts.



P.O. 600 Type (Minor) relay with a combination of heavy-duty and light-duty contacts for space and cost saving.

KEYSWITCH
RELAYS

Production Director

2 Irongate Wharf Road, Praed St., London W.2

Tel: PADdington 2231

Extremely advantageous quotations can be offered for quantity orders. Contractors to Home and Overseas Governments and H.M. Crown Agents.

RELAYS FOR ALL PURPOSES can be supplied to customers' requirements. For

AUTOMATION
COMPUTERS
BATCH COUNTING & PHOTO ELECTRICS
TELEPHONY & INTERCOM. SYSTEMS
AUTO-TIMING & AUTOMATIC SIGNALS
MOTOR & MACHINERY CONTROL
CURRENT & VOLTAGE REGULATION Etc.

Tick **No 129** on reply card for further details

Tick **No 130** on reply card for further details

PLAN your visit to LONDON for 23-28 MAY

INSTRUMENTS I
ELECTRONICS E
AUTOMATION A

exhibition

over 500 exhibitors from

Austria	Great Britain
Belgium	Holland
Czechoslovakia	Italy
Denmark	Poland
East Germany	Switzerland
France	United States
West Germany	

OLYMPIA LONDON
23-28 MAY 1960

Open 10 a.m. - 6 p.m. daily

Admission 5/-
Season Ticket 10/-

Further details from
Industrial Exhibitions Ltd.,
9 Argyll Street, London, W.1.

LARGEST IN THE WORLD

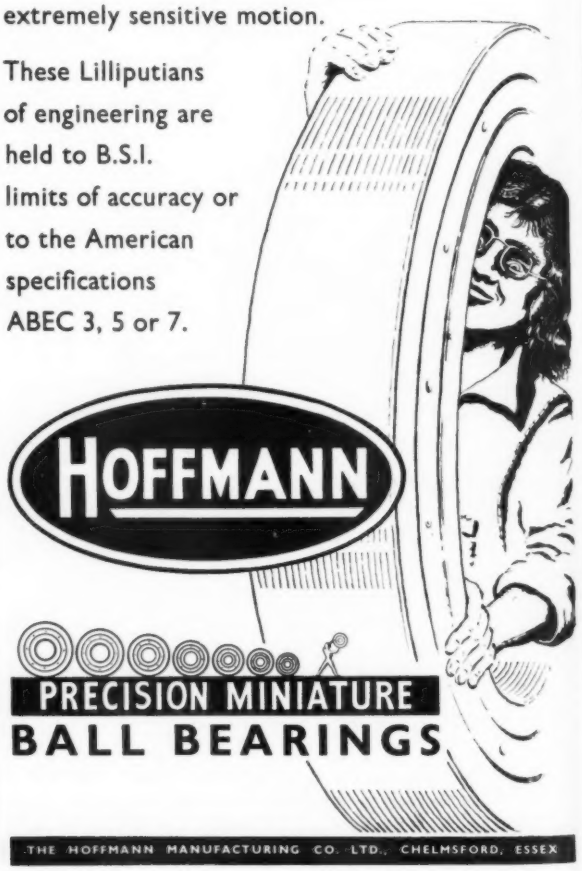
Tick **No 131** on reply card for further details

Brobdingnagian or Lilliputian?

It is improbable that Dean Swift had any thoughts about ball bearings in his curious romancings, but he would, we believe, appreciate the well-balanced design and fine finish of both our big and little fellows.

We have made bearings as large as 5 ft. diameter to support a locomotive turntable whilst their tiny counterparts, some as small as 3 mm. diameter, may be used on a very high speed dental drill, or perhaps for an instrument where the need is not for speed but extremely sensitive motion.

These Lilliputians of engineering are held to B.S.I. limits of accuracy or to the American specifications ABEC 3, 5 or 7.



HOFFMANN

PRECISION MINIATURE
BALL BEARINGS

THE HOFFMANN MANUFACTURING CO. LTD., CHELMSFORD, ESSEX

Special Project

A special project, being the result of special thought, demands a careful choice of materials. The four cooling oil jackets of the R.F. particle accelerator—part of the 7 GeV proton synchrotron sited at the Rutherford High Energy Laboratory, Harwell—have to be structurally strong but non-magnetic. Each has to carry 3,000 lbs of ferrite core in oil at 9 p.s.i.g. The choice was glass cloth/epoxy resin laminates moulded by Marston.
Marston's experience proves that reinforced plastics, used appropriately, are better, cheaper and weight-for-weight stronger than equivalent constructions in metal.
And they combine resistance to fire and corrosion with electrical and thermal insulation.

Reinforced plastics could solve your design problem —why not consult us now ?

MARSTON EXCELSIOR LTD
(A subsidiary company of Imperial Chemical Industries Limited)
FORDHOUSES, WOLVERHAMPTON

MAR.271

Tick **No 133** on reply card for further details

interested in Pure metals?

chromium — four purity grades available all over 99.0% pure.

niobium — available as beads, roundels, electrodes and ingots.

silicon — seven purity grades available, all over 98.0%.

tantalum — available as roundels, dendrites, electrodes and many wraught shapes.

vanadium — powder at 99.5% purity grade, mill products at higher purity.

MANY CHEMICAL COMPOUNDS ARE AVAILABLE OF THESE AND OTHER METALS

Full information on rarer metals and their compounds is available on request.

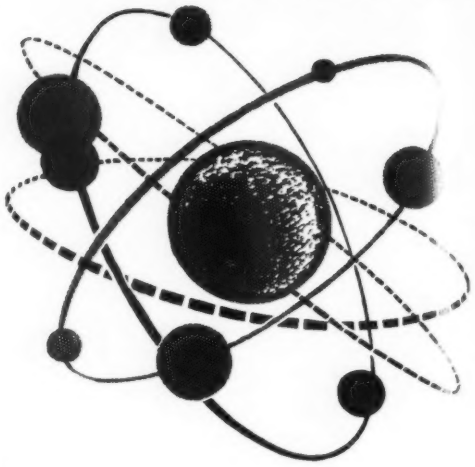
UNION CARBIDE TRADE MARK

Alloys Division

UNION CARBIDE LTD

R4. 103 MOUNT STREET, LONDON, W.1

Tick **No 134** on reply card for further details



FOR ALL SURFACES WHICH MAY HAVE TO BE DECONTAMINATED

Detel ATOMICOTE

tested and approved by A.E.R.E. HARWELL

COMPREHENSIVE DATA ON CONTAMINATION/DECONTAMINATION PROCEDURES CARRIED OUT ON

ATOMICOTE

FROM

DETEL PRODUCTS LTD

SOUTH RUISLIP

MIDDLESEX

RUISLIP 6041/2

DETEL PROTECTIVE COATINGS DEFIES CORROSION

a full range of rugged industrial compressors

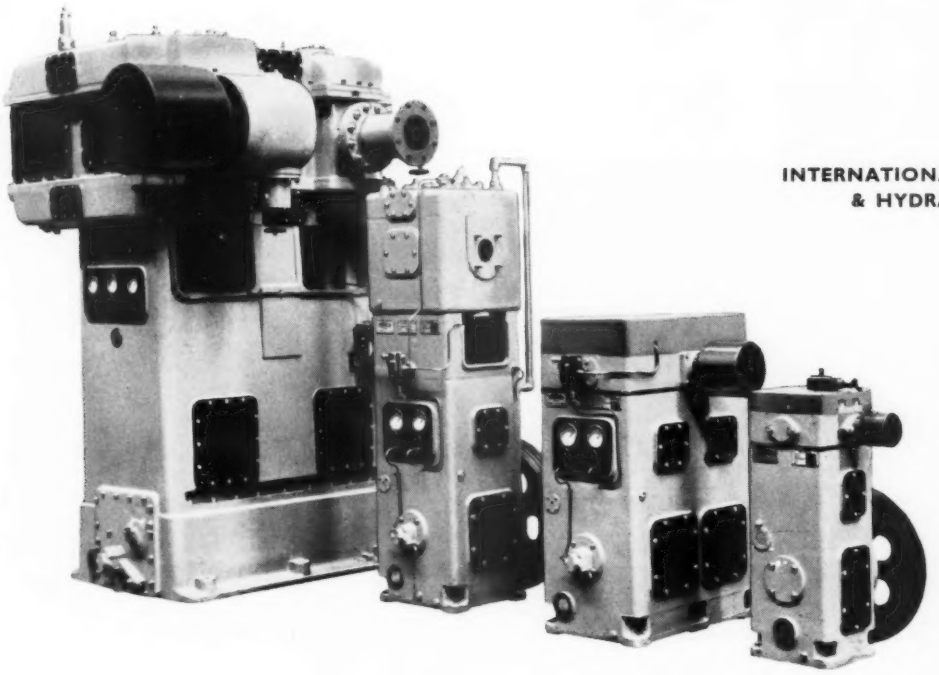
The large Compressor illustrated is typical of our 'Comoblok' range of machines. This range covers capacities from 500 — 2,000 c.f.m. These machines are of the double-acting crosshead type, and are suitable for pressures up to 50 p.s.i.g. single stage, and 150 p.s.i.g. two stage. They are remarkable for their low power consumption and compact design.
Send for Leaflet No. T29.

The machine alongside is one of our Oil-free Range. These are available in capacities from 100 to 2,000 c.f.m., and at all pressures up to 150 p.s.i.g. They are specifically designed to deliver uncontaminated air, and have many special features incorporated which make them unique in this field of Compressors. Send for Leaflet No. T31.

The two smaller machines shown illustrate our 'Uniblok' and 'Twinblok' Range, and cover capacities of from 50 to 400 c.f.m. at all pressures up to 120 p.s.i.g. These are of the single stage, single acting type, styled to give a neat appearance and are unrivalled for their low maintenance and space saving features. Send for Leaflet No. T19.

Tilghman's have a complete range of Vacuum Pumps to offer in displacements from 500—2,500 c.f.m., and are capable of drawing 28" Hg. on a 30" Hg. barometer.

Tilghman's undertake the design and manufacture of special purpose Air & Gas Compressors, Boosters, etc., and welcome an opportunity of quoting for complete installations.



We are exhibiting at the
INTERNATIONAL COMPRESSED AIR & HYDRAULICS EXHIBITION
Visit us on stand
No. 31

Send for our informative and valuable leaflet on "Selection, Installation and Maintenance of Air Compressors"

TILGHMAN'S *Limited* **AIR POWER DIVISION**
BROADHEATH · ALTRINCHAM · CHESHIRE

TELEPHONE: ALTRINCHAM 4242 (6 LINES) TELEGRAMS: TILGHMANS ALTRINCHAM
A Member of The Staveley Coal and Iron Co. Ltd. Group

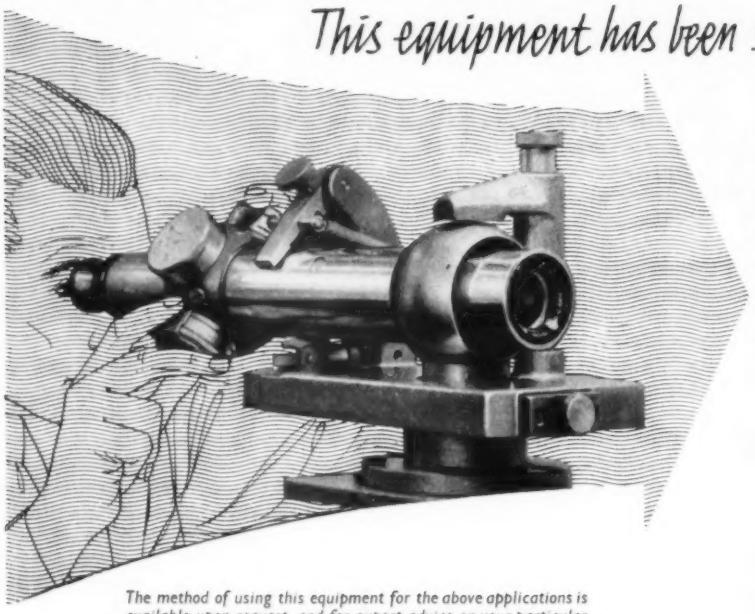
T255

Tick **No 135** on reply card for further details

Tick **No 136** on reply card for further details

'MICRO' ALIGNMENT TELESCOPE

This equipment has been successfully used by ...



...the United Kingdom Atomic Engineering Research Establishment in the construction of Experimental Nuclear Reactors and the associated Projects ZETA, BEPO, ZEUS, ZEPHYR, DIDO and PLUTO. Also used by the leading manufacturing groups in the construction of Nuclear Power Stations, of the Power Supply Plan in Great Britain.

Sets and checks **ALIGNMENT PARALLELISM · SQUARENESS PLANE SURFACES**

The method of using this equipment for the above applications is available upon request, and for expert advice on your particular problem, please apply to Optical Tooling Engineers' Dept.

A Division of KASK PRECISION INDUSTRIES LTD.

TAYLOR-HOBSON

TAYLOR, TAYLOR & HOBSON, LEICESTER, England. AT 29

for CATHODIC PROTECTION

or WELDING INSPECTION

call in MAPEL

MAPEL

METAL & PIPELINE ENDURANCE LTD.,

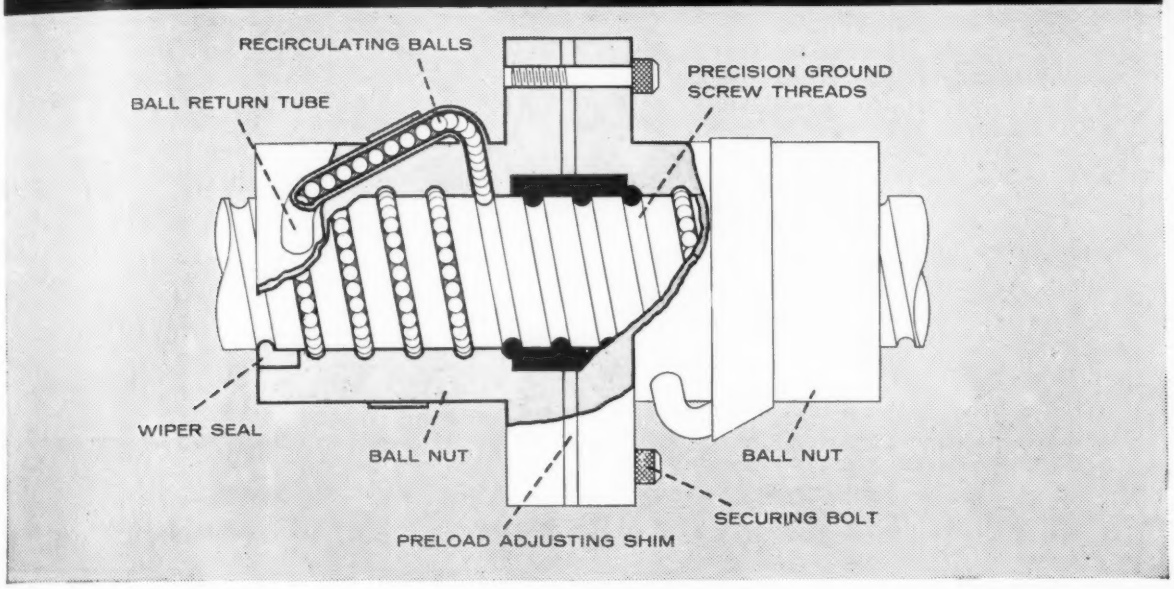
30 London Road, Woolmer Green, Herts.

Tel: Knebworth 3083 Grams: Metaldure, Knebworth

Other offices at London, Newcastle-upon-Tyne and Glasgow

WORLD-WIDE SERVICE

Beaver pre-loaded ball screws, up to 95% efficient, operate at -52°C to over 400°C with no backlash...



...ANOTHER ENGINEERING ADVANCE FROM BRISTOL SIDDELEY

Bristol Siddeley Engines Limited produce Beaver* pre-loaded ball screws. These ball screws achieve a minimum efficiency of 90% and they can operate within a temperature range of −52° C to 400° C without lubrication, and up to 170° C when lubricated.

Machined and ground to the highest standards of precision engineering Beaver pre-loaded ball screws greatly increase transmission efficiency. They reduce the power required for actuation by as much as 80%, when converting rotary drive into linear output or force input into torque output. By eliminating backlash, with pre-loading, they give precise control over very small increments of motion and a high response frequency. And when compared to conventional screw mechanisms, they provide a predictable operating life which is much longer, require much less maintenance and give more trouble-free operation.

Basic design application analysis

Bristol Siddeley engineers make an exhaustive analysis of each specification. And each unit is specially designed for its particular application. Beaver ball screws are made automatically reversible or with controlled "no-back," with multiple or single circuits. Beaver pre-loaded ball screws have been proved as the most efficient method of converting rotary into linear thrust in over 2,700 engineering applications in many branches of industry. They have been designed already with rated operating load capacities of 370,000 lb (825,000 lb maximum static load) but the maximum potential operating load is, in most cases, limited only by the requirement.

Bristol Siddeley Beaver ball splines have been developed to eliminate the disadvantages of conventional splines. The designs are very effective in minimising friction, particularly when high torsional and bending loads are imposed during linear movement.

** Complete technical and manufacturing co-operation with Beaver Precision Products Inc., Detroit.*

For further information please write to J. B. Starky, Sales Manager (Beaver Products Division), Bristol Siddeley Engines Limited, PO Box 17, Coventry, England.

BRISTOL SIDDELEY ENGINES LIMITED

Tick **No 138** on reply card for further details

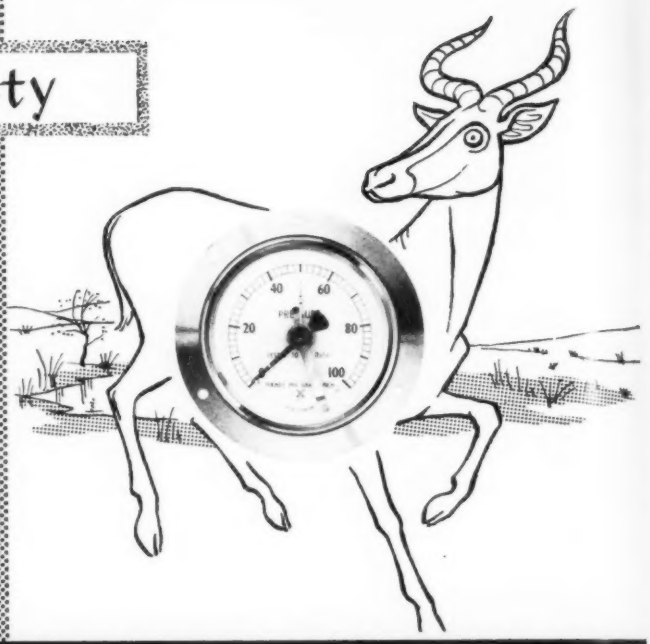
Tick **No 139** on reply card for further details

Sentinel of Safety

The Hartebeest is described as the sentinel of the veldt the most alert of all antelopes. In industry it is P. & G. electric contact gauges that give warning of action required and they may also be arranged to provide automatic control.

Several types are available with single or double contacts to operate on rising or falling pressures.

Electric contact gauges can safeguard vital equipment, prevent breakdowns and save money. Send us details of your problems and we shall be pleased to offer our advice.

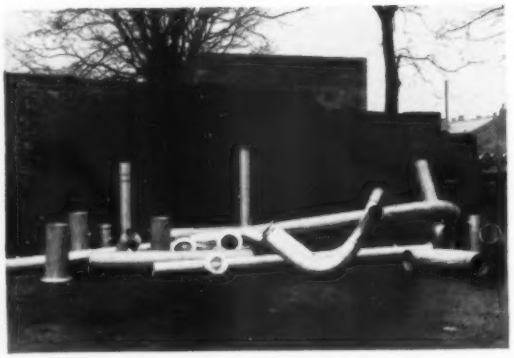


WINDMILL

Payne & Griffiths Ltd

TUDOR WORKS · WINDMILL LANE
SMETHWICK · BIRMINGHAM

Specialists in Aluminium Alloy Plate and Structural Fabrications of all descriptions



One of the first users of the Argon Arc welding process in the country, we again lead in the installation of the Sigmette Fine Wire welding equipment which opens a new field in the welding of Aluminium and its alloys, Non-Ferrous metals and Stainless Steels

Heat Exchangers
Pressure Vessels
Structural Aluminium of all descriptions
Smooth bore pipes and fittings up to 24" diameter

Your enquiries would receive our immediate attention

Illustrated is an 8" and 12" Bore Pipe Installation fabricated for the Ministry of Supply

E. C. PAYTER & CO. LIMITED

MEETING ST., GREAT BRIDGE, TIPTON, STAFFS. *Tel.:* TIPTON 2121

FOR SHAFTS ROTATING AT HIGH SPEEDS

Ensure 100% OCCLUSION. Specially designed and produced for the purpose – Weston IMPAX Seals are established for use on high speed rotating shafts, coupled with high fluid temperatures and pressures. A new series has been developed, using the most advanced materials to keep pace with the quickening tempo of modern machine operation.

Send for new Catalogue now to: Complete range of Seals available.

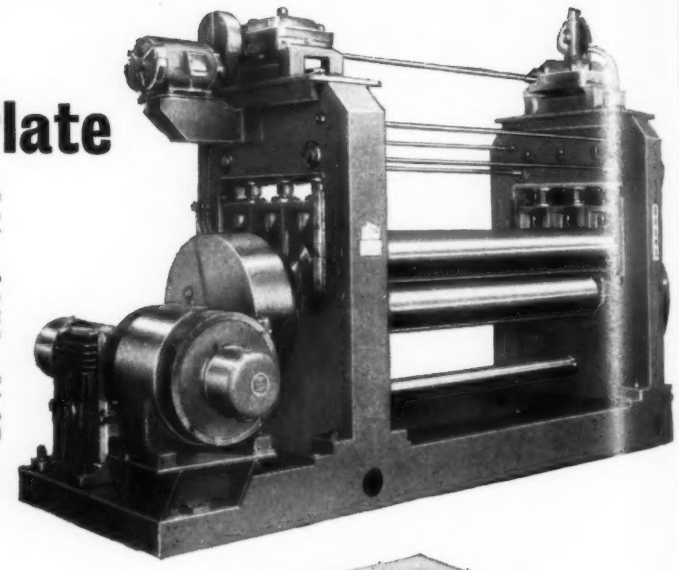
CHARLES WESTON & CO. LTD.

Irwell Bank Works, Douglas Green, Pendleton, Salford, 6

Telephone: Pendleton 2857-8-9. Telex: 66-255 · Birmingham: Erdington 5459 · London: Holborn 0414. Telex: 2-2682

Tick **No 142** on reply card for further details

For levelling Mild Steel Plate



This Bronx 5-Roll Plate Levelling Machine is suitable for levelling cold mild steel plate up to a maximum of 8ft. in width by ¾in. thickness, and is designed for a levelling speed of 16ft. per minute.

The levelling rolls consist of three top and two bottom rolls, all of which are 12½in. diameter. The roll necks are finished ground, and the bearing assembly so arranged as to preclude entry of scale and other foreign matter.

The top rolls are adjustable by hand with large handwheels provided, or by a 7½ h.p. reversing motor running at 950 r.p.m. The machine is designed to operate continuously at the maximum specified load and output.

Similar models made in all sizes, to specification.

BRONX

5-ROLL PLATE LEVELLING ROLLS

There are also Bronx Press Brakes, Guillotine Shears, Bending Rolls, Section Straightening Machines, etc. Write for Catalogues.

BRONX ENGINEERING CO. LTD., LYE, WORCESTERSHIRE **Tel. LYE 2307/8**

70

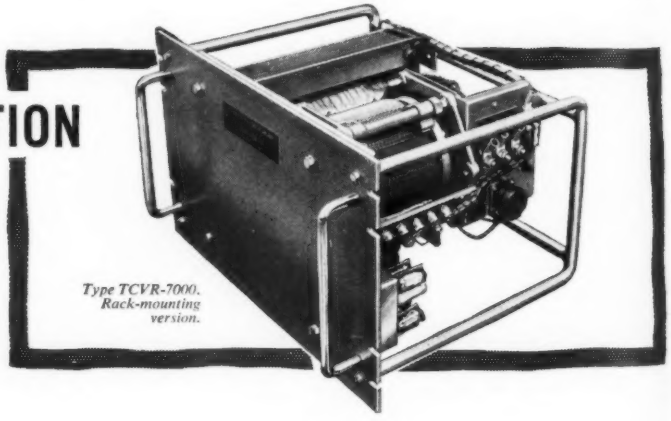
40 VOLTS/SEC AUTOMATIC CORRECTION

—with the type TCVR voltage regulator

The TCVR is a servomechanical automatic voltage regulator having the very high speed of correction of FORTY VOLTS PER SECOND. It provides an *undistorted* output, maintained constant within very close limits (normally ±0.5%) from no-load to full-load, for wide variations in frequency and power factor.

A wide range of models from 1.6 to 12 kVA single-phase, and 4.8 to 36 kVA three-phase, is available, to standard or tropical specification, in cabinets or for rack-mounting. Models are also available in which the output voltage is continuously adjustable over a wide range by means of a panel control. Regulators can be supplied to Services' specification, and special models can be designed to order.

For high-speed, accurate stabilisation *without distortion*—**specify TCVR.**



Type TCVR-7000. Rack-mounting version.

Other products of Claude Lyons Ltd. Stabiliser Division

BMVR: Motor-driven laboratory and industrial regulators ranging from 1·6 to 29 kVA single-phase, and 4·8 to 87 kVA three-phase. Constancy of output normally ± 0·5% from no-load to full-load. No distortion. Speed of correction 1 Volt/Sec. A great variety of models, standard, tropical and militarised, for all applications.

BAVR: Electronic stabilisers of very high accuracy, and very rapid response, with no moving parts. Input range : − 10% to + 5%, output constancy ± 0.15%. Three sizes : 200, 500 & 1000 VA. Exceptionally useful for control of chemical processes, heating, lighting, etc.

ASR: Automatic step regulators, small, inexpensive, and with sinusoidal output waveform. Two sizes : 1·15 kVA and 2·3 kVA. Input range − 10% to + 5%; output constancy, ±2½%.

ATC: Automatic Tap-Changing Transformers — a development of ASR. Two sizes : 575 VA and 1150 VA. Input range − 20% to + 10% : output constancy, ± 5%. Provide adequate stabilisation for many types of apparatus, at low cost. Also useful as pre-regulators, e.g. in conjunction with BAVR.

We shall be pleased to send you full details of our entire range.

Claude Lyons Ltd.

Stabiliser Division **VALLEY WORKS · HODDESDON · HERTS · TELEPHONE HODdesdon 4541-4**

CL/47/E2B.

E.M.I. Portable Contamination Monitor Type 1

THE HEART OF TODAY'S
EFFICIENT RADIATION MONITORS

The widespread use of scintillation counters in health physics work owes much to the continuous development by E.M.I. Electronics Ltd. of photomultiplier tubes, particularly those with large end-window cathodes, first introduced by E.M.I. in 1948.

E.M.I. PHOTOMULTIPLIERS

For efficiency, sensitivity and convenience, the scintillation counter, using a photomultiplier in one of its many current E.M.I. forms, is undoubtedly the most universally useful device for the detection and measurement of alpha, beta and/or gamma rays.

The range of E.M.I. photomultiplier tubes is probably the largest in the world. Besides an extensive list of standard types effectively covering all the principal photo-electronic applications, special tubes can also be produced to suit specific problems. Send us your enquiries—our design team will gladly co-operate with you.

EMI

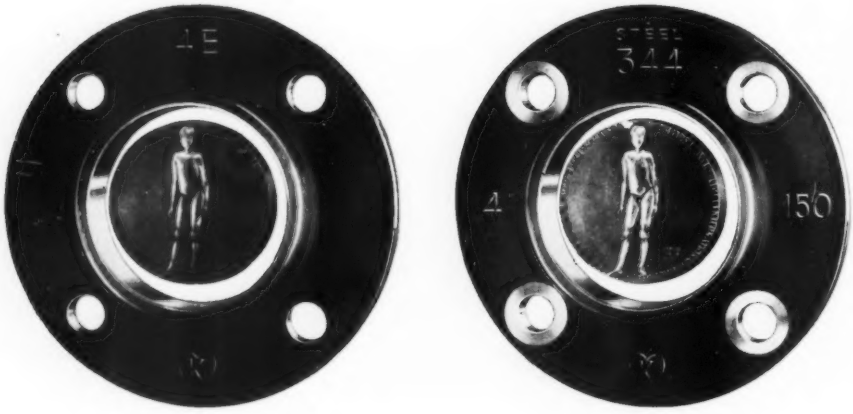
E.M.I. ELECTRONICS LTD
VALVE DIVISION · HAYES · MIDDLESEX
TELEPHONE · SOUTHALL 2468

EE72

Tick **No 144** on reply card for further details

Tick **No 145** on reply card for further details

The eyes of the World...



are on K FLANGES

TRADE MARK

SPECIFY BUY AND USE
THE WORLD'S BEST
FLANGES FROM

The only flanges to be awarded a silver and bronze medal at the World's Fair, Brussels

KIRK'S *other products included in the award are* Malleable Fittings, Fabricated Pipework, Welded Fittings, Welded Seamless Steel Tubes and Fittings, Malleable Iron Castings, Drop Forgings, Valves.

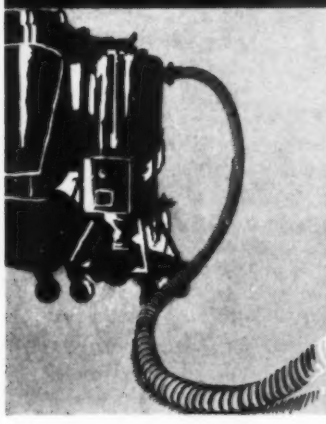
KIRK & CO. (TUBES) LTD.

74/82 PARADISE ST · LONDON · S.E.16 · BERMONDSEY 3156/7/8
and at MANCHESTER · WALSALL · PONTYCLUN

VACU-BLAST

for shot blasting tubes of any size from $\frac{1}{8}$ inch bore upwards

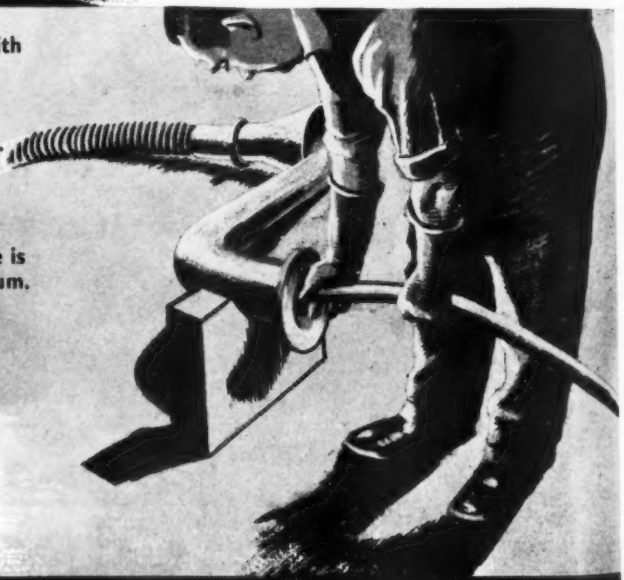
the only effective way to remove scale, fused sand and corrosion products from the internal surface of tubes of practically any shape or size.



used in conjunction with the Vacu-Blast Major machine, these simple attachments ensure a perfectly clean surface.

All dust and debris is confined within the Vacu-Blast closed system. Spent abrasive is recovered under vacuum.

Can be used in the open shop or in the field.



We invite you to submit sample tubes so that we may demonstrate the method and advise on plant accessories to suit your requirement

VACU-BLAST LIMITED, BATH ROAD, SLOUGH, BUCKS, ENGLAND.
TELEPHONE : SLOUGH 24507/9

CROSBY Safety/Relief valves are chosen for

.PERFORMANCE
.ADAPTABILITY
.MAINTENANCE

Lower priced valves can be produced which will "do the job", but will their performance, reliability, adaptability and maintenance requirements keep operating and maintenance costs and shut-down time to an absolute minimum ?

CROSBY DESIGN—The Crosby JO & HS Full Nozzle, Full Lift Relief and Safety valves are the only valves having both easily adjusted, two ring control and truly flat seats on both disc and nozzle.

HIGH PERFORMANCE—Safety/Relief valves rely on fluid kinetic forces just as much as static pressure for correct operation. Without an adjustable guide ring to vary the secondary orifice to suit different fluids the secondary orifice contours would have to be individually machined to suit each application for optimum performance and cannot be expected to be completely satisfactory on fluids other than that for which the valve was ordered.

WIDE ADAPTABILITY—The adjustment possible with the Crosby two ring control enables optimum performance of pop, lift, capacity, blowdown and shut-off to be readily obtained on all fluids, thus providing complete adaptability.

EASY MAINTENANCE—The perfectly flat seats on both nozzle and disc can very easily be resurfaced when necessary without the necessity of critical control of seat widths and angles; in fact the tools can easily be taken to the valve; it does not have to be taken to the tools.

The Crosby one-piece disc can be resurfaced many times without costly replacements. Also any dimensional changes due to resurfacing can easily be compensated for by ring adjustment, ensuring optimum performance.

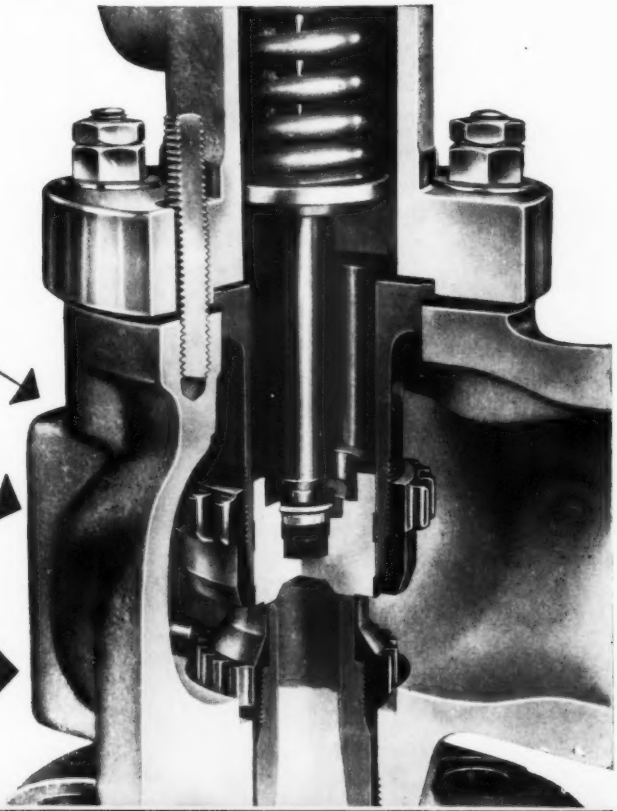
CROSBY

UNIQUE FEATURES

BLOWDOWN CONTROL
Guide ring accurately adjusts to required blowdown by changing the reactive forces of the various flowing media. Blowdown adjustment is independent of pop action.

FLAT SEATS
Both nozzle and disc seats are completely flat and easily resurfaced if necessary without replacement parts.

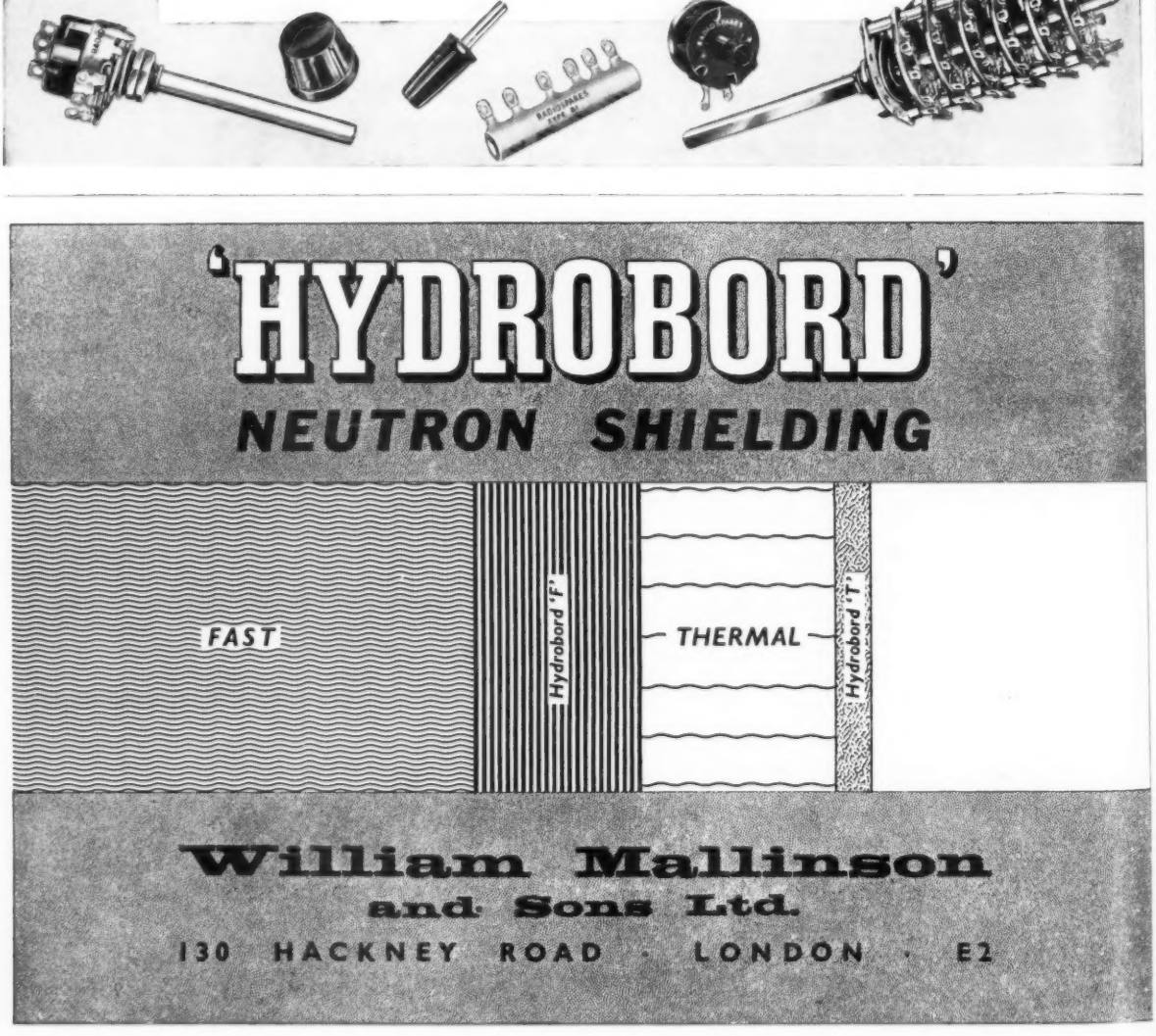
POP ACTION CONTROL
Adjustable nozzle ring assures sharp controlled pop action . . . prevents long drawn-out warn or simmer before popping.



CROSBY VALVE & ENGINEERING CO. LTD. · WEMBLEY · MIDDLESEX · ALPerton 2311

Tick **No 147** on reply card for further details

TO DESIGNERS, PROTOTYPE & MAINTENANCE ENGINEERS
A 24 hr Service
FOR
ELECTRONIC COMPONENTS
We produce a comprehensive range of high-quality Electronic Components. Consult our catalogue for your requirements. Our "By Return" Service will ensure immediate despatch of your orders.
Radiospares Ltd.
4-8 MAPLE STREET, LONDON, W.1, ENGLAND
Tel.: EUSton 7232-7
Telegrams: RADOSPERES, WESDO, LONDON. Cables: RADOSPERES, LONDON.


'HYDROBORD'
NEUTRON SHIELDING
FAST
Hydrobord 'F'
THERMAL
Hydrobord 'T'
William Mallinson
and Sons Ltd.
130 HACKNEY ROAD · LONDON · E2

東海村

TOKAI-MURA

At Tokai-Mura, 70 miles north-east of Tokyo, The General Electric Company Limited of England is to build Japan's first nuclear power station. This 150 MW station will be powered by a single gas-cooled graphite-moderated reactor of the same basic type as the two which are being built by G.E.C. at Hunterston in Scotland. In producing a design to ensure the safety of the installation even under severe earthquake conditions, G.E.C. and her associate Simon-Carves Ltd., have brought to bear the results of much experimental work. For example, models of the pressure vessel mounted on a supporting skirt were subjected to horizontal loads such as would arise from earthquake shock.
Unique protective devices will be provided capable of effective operation even if the core should be severely damaged and tilted to an angle of 45°. In addition to the normal control rod system there is a unique arrangement of boron steel balls which would be released into the channels in the core by seismic pick-ups outside the station or by displacement of the pressure vessel, the core itself, the grid or various other critical parts of the reactor. The station is expected to be in full operation in 1963.

G.E.C.
AND SIMON-CARVES LTD

ATOMIC ENERGY DIVISION
THE GENERAL ELECTRIC COMPANY LIMITED OF ENGLAND, ERITH, KENT

Tick **No 151** on reply card for further details

NEW K FROM K.D.G.

'K' SERIES
PRESSURE GAUGES

Brand new and made to last, is this New Long Life Pressure Gauge by K.D.G. It is guaranteed not to have an error greater than ± 1% of the full scale deflection between 10 and 90% of maximum scale reading, the remainder of the scale being within ± 1½%. Conforming to British Standard Specifications 1780: 1951.

- ★ Stainless Steel Mechanism
- ★ Heavy duty BOURDON TUBE design
- ★ Easy to read dial layout
- ★ Safety Blow-out Discs
- ★ Extensive Life . . . at a competitive Price

CRAWLEY KDG LONDON

Full details and specifications of the complete K.D.G. range are readily available from:

K.D.G. INSTRUMENTS LTD.,

In association with Stow & Partners Ltd.

MANOR ROYAL, CRAWLEY, SUSSEX · Crawley 25151
London Showrooms, Service and Sales: 100 Fleet Street, E.C.4 · Tel.: FLEet 5354/5

BENDING and STRAIGHTENING PRESS

by
HENRY BERRY

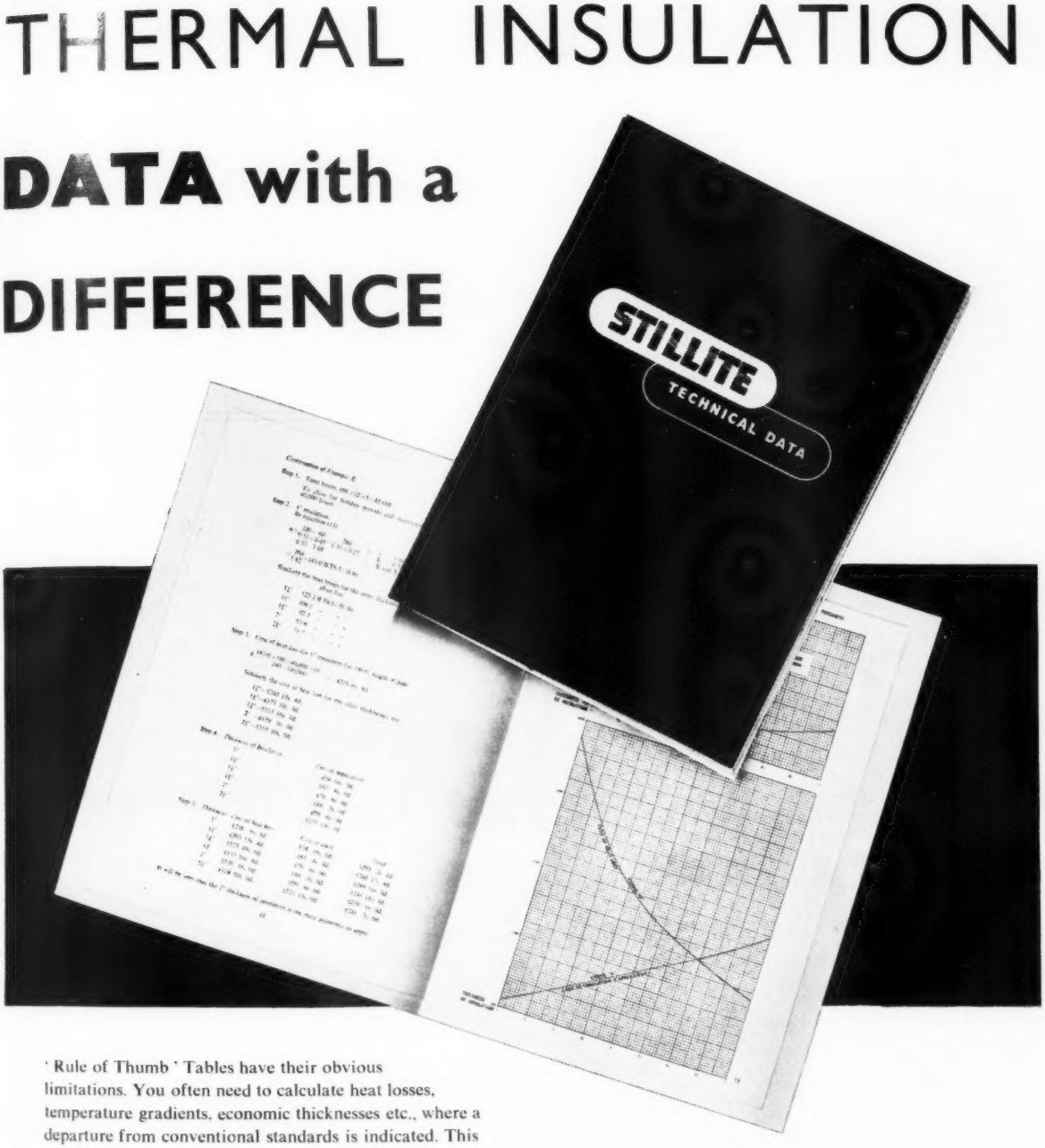
This Bending and Straightening Press is a special type designed for performing work on steel bars up to 14" dia. Of exceptional robust construction, ideally suited to steel works duty.

We also manufacture:
High Pressure Hydraulic Plant for Shipyards and Railway Workshops, Plate Bending Rolls, Punching and Shearing Machines, Continuous Finishing Presses for Silks and Rayons, Veneer and Plywood Presses, Cotton Baling Presses, Die Spotting Presses, Pumps, Accumulators, Valves and Intensifiers.

HENRY BERRY & CO. LTD.
CROYDON WORKS, LEEDS 10 TEL: LEEDS 75481-2 GRAMS: "RIVETTER LEEDS 10"

THERMAL INSULATION

DATA with a DIFFERENCE



'Rule of Thumb' Tables have their obvious limitations. You often need to calculate heat losses, temperature gradients, economic thicknesses etc., where a departure from conventional standards is indicated. This Manual gives you the Data you need—the Basic Formulae with examples, tables and graphs and the Theoretical considerations involved.

STILLITE
Regd. Trade Mark

STILLITE PRODUCTS LTD.

15 Whitehall, London, S.W.I. WHItehall 0922-7
And at 231 St. Vincent St., Glasgow, C.2. CENtral 4292

COUPON FOR STILLITE TECHNICAL DATA MANUAL
Please attach to letterhead and post to
Stillite Products Ltd. 15 Whitehall, London, S.W.I.

NAME .....

ADDRESS .....

.....

NUCLEAR POWER

Tick **No 153** on reply card for further details

The above illustration shows a selective range of pure molybdenum articles fabricated by machining or spinning. We shall be pleased to quote against customers' drawings.

MUREX LTD *(Powder Metallurgy Division)* RAINHAM • ESSEX
Telephone: Rainham, Essex 3322. Telex 28632 Telegrams: Murex, Rainham-Dagenham Telex
LONDON SALES OFFICE: CENTRAL HOUSE, UPPER WOBURN PLACE, W.C.I

the MARK II "CL"

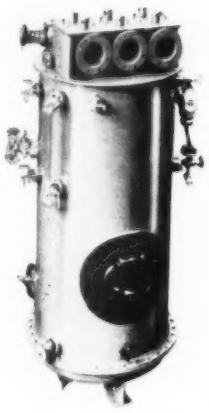
High Pressure Valve

- *CORROSION RESISTING STEEL DOOR*
- *P.T.F.E. 'FLUON' SEATING RINGS*
- *SIMPLE AND ROBUST IN CONSTRUCTION*
- *POSITIVE IN OPERATION*
- *NO WEDGES OR SPRINGS*
- *SPINDLE STUFFING BOX FITTED WITH CHEVRON PACKING*
- *STANDARD TEST PRESSURE 100 p.s.i.g*
- *RAISED FACE FLANGES SUPPLIED BLANK OR DRILLED TO B.S.10 TABLES 'A' TO 'E' INCLUSIVE*
- *INTERNAL SCREW WITH OR WITHOUT INDICATOR*

SIZES 2" TO 24" BORE
VERTICAL OR HORIZONTAL

THE BRYAN DONKIN COMPANY LTD.
CHESTERFIELD TEL: 3153 · LONDON TEL: ABBEY 1096

Wasted Heat!



A 3 unit Down Flow waste heat boiler

For centuries mankind has dreamed of harnessing the power and heat of the volcano to serve rather than destroy him, but still the wastage of heat continues. Heat Wastage occurs not only in Volcanoes: throughout the World manufacturing plants and ships continue to run in semi-harness, but not Spanner's Clients. They use Spanner Waste Heat Boilers to put to work the heat of exhaust gases from their engines and furnaces with a resultant boost in thermal efficiency. The whole of the Spanner range of boilers has the exclusive "Swirlyflo" tube, designed to extract the maximum heat, and in turn making possible compactness of design with a resultant saving in space.

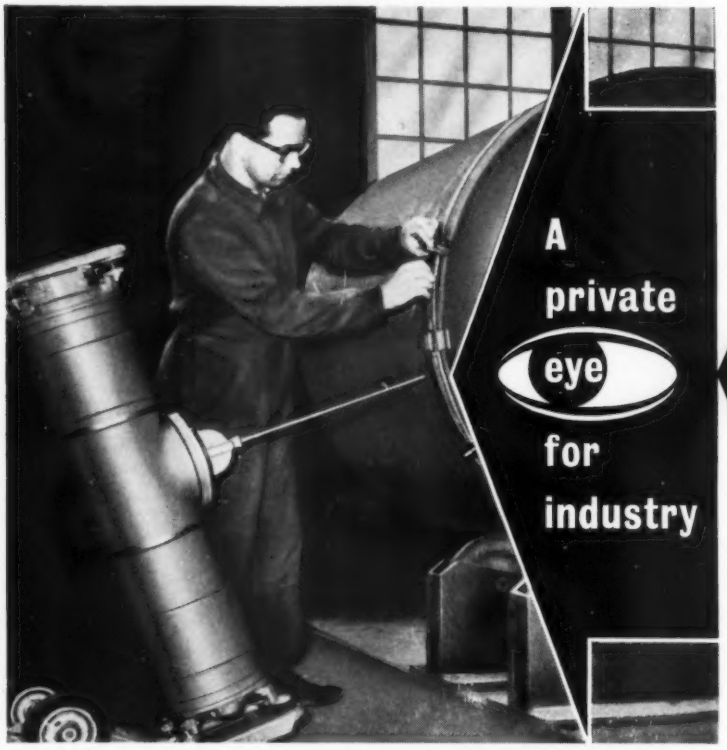
Spanner have the answer to all your waste heat problems.

SPANNER BOILERS LIMITED

WOKINGHAM ROAD · BRACKNELL · BERKS.

TELEPHONE: BRACKNELL 1500
TELEGRAMS: SWIRLYFLO, BRACKNELL, TELEX.
TELEX: 84130.

Tick **No 156** on reply card for further details



Ruggedly built, but still mobile, the Muller Macrotank H is specially developed for on-site radiographic examination in heavy industry, ship and bridge building, nuclear power and refinery construction — wherever complete and accurate weld examination is essential. The small focus (2.3 mm.) of the Macrotank H gives really sharp definition, with a penetration of up to 2½" of steel with Pb screens in reasonable exposure time. It is low in cost, reliable in use, and backed by full service facilities which may be on contract if desired. We shall be glad to send you full details.

The Macrotank H is a product of C. H. F. Muller, Hamburg.

Sole Distributors in U.K.

RESEARCH AND CONTROL INSTRUMENTS LIMITED

Instrument House, 207, King's Cross Road, London, W.C.1. TERminus 2877

(RCL0410A)

"B-W" *Flowline Heaters...*

The illustration shows a recent batch of 'B-W' 65 KW electrically-heated units with their associated Control Panels. These Gas and Air Flowline Heaters are representative of the wide range of Barlow-Whitney custom-built process equipment supplied to the Nuclear and Chemical industries and heated by electricity, gas or other fuels.

WRITE FOR FURTHER DETAILS QUOTING REFERENCE C260

PROCESS HEATING

Barlow-Whitney

BARLOW-WHITNEY LTD., 2 DORSET SQUARE, LONDON, N.W.1. Tel: AMBassador 5485 Works: LONDON & BLETCHLEY

BMJ

AN ANNOUNCEMENT FROM ULTRA . . .

Since the Special Products Division of Ultra Electric Limited was formed in 1946, the demand for its specialised services in the field of electronic engineering has grown steadily. To meet the increase in the number and complexity of these commitments, a programme for expansion and re-organisation was recently completed and the Division has been re-formed as an autonomous Company known as ULTRA ELECTRONICS LIMITED.

The Company has first-class facilities for research, development and production. Current activities include work on radio and radar system applications, magnetic amplifier servo controls, aircraft intercommunication, submarine detection, and computer peripheral equipment.

The Continental Connector Division of the new Company manufactures the precision miniature multi-way connector of that name.

ULTRA

ULTRA ELECTRONICS LIMITED
WESTERN AVENUE · LONDON · W3 · Tel: ACOrn 3434

Tick **No 159** on reply card for further details

Tick **No 160** on reply card for further details

PROBLEM SOLUTION

Sequence pumping is occasionally required in a hand-operated pumping plant which, although intended to be used spasmodically, must also be guarded against failure of water supply. Other pre-requisites are rough and fine pumping; isolation and air admittance.

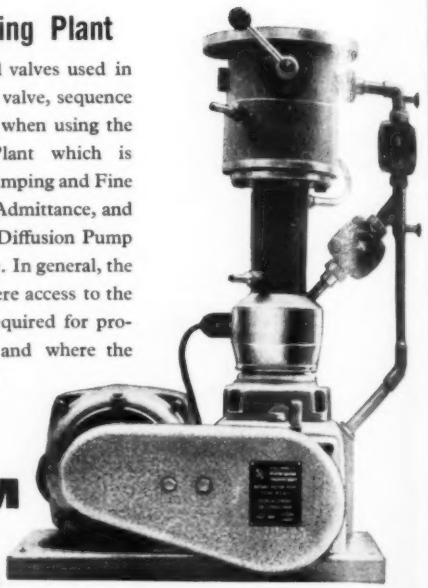
the answer came from –

N·G·N

Rotary pumps, diffusion pumps, valves, combined units—these are but a few from the very full range of equipment now being produced for the High Vacuum industry by N.G.N.....our technical services are being increasingly used to assist and advise on problems of High Vacuum. Why not make use of them—NOW.

Type HCU Pumping Plant

By means of the two hand valves used in conjunction with the baffle valve, sequence pumping may be obtained when using the Type HCU Pumping Plant which is equipped to give Rough Pumping and Fine Pumping, isolation or Air Admittance, and water relay to protect the Diffusion Pump against water supply failure. In general, the HCU is more suitable where access to the vacuum chamber is not required for production sequence cycles, and where the plant is not likely to be left running overnight without supervision.



N.G.N. FOR HIGH VACUUM

High Vacuum Specialists and Electrical Engineers

N.G.N. ELECTRICAL LIMITED
Avenue Parade, Accrington, Lancs.
Telephone: Accrington 5611-2

The Sign of MBM LIMITED *Quality*

Introducing the M.B. Metals group

the complete service for Industry

consult us now!

If you have problems concerning the Design, Development, Manufacture and Environmental Testing of

ELECTRO-MECHANICAL COMPONENTS (*including terminations*)
ELECTRO-MECHANICAL EQUIPMENT
ELECTRONIC EQUIPMENT & COMPLETE SYSTEMS

Please visit our laboratories

Our ENVIRONMENTAL TESTING LABORATORIES also provide a service for the testing of components and equipment that has been developed by industry

THE FACILITIES FOR ALL THE ABOVE ARE PROVIDED WITHIN THE M.B. METALS GROUP

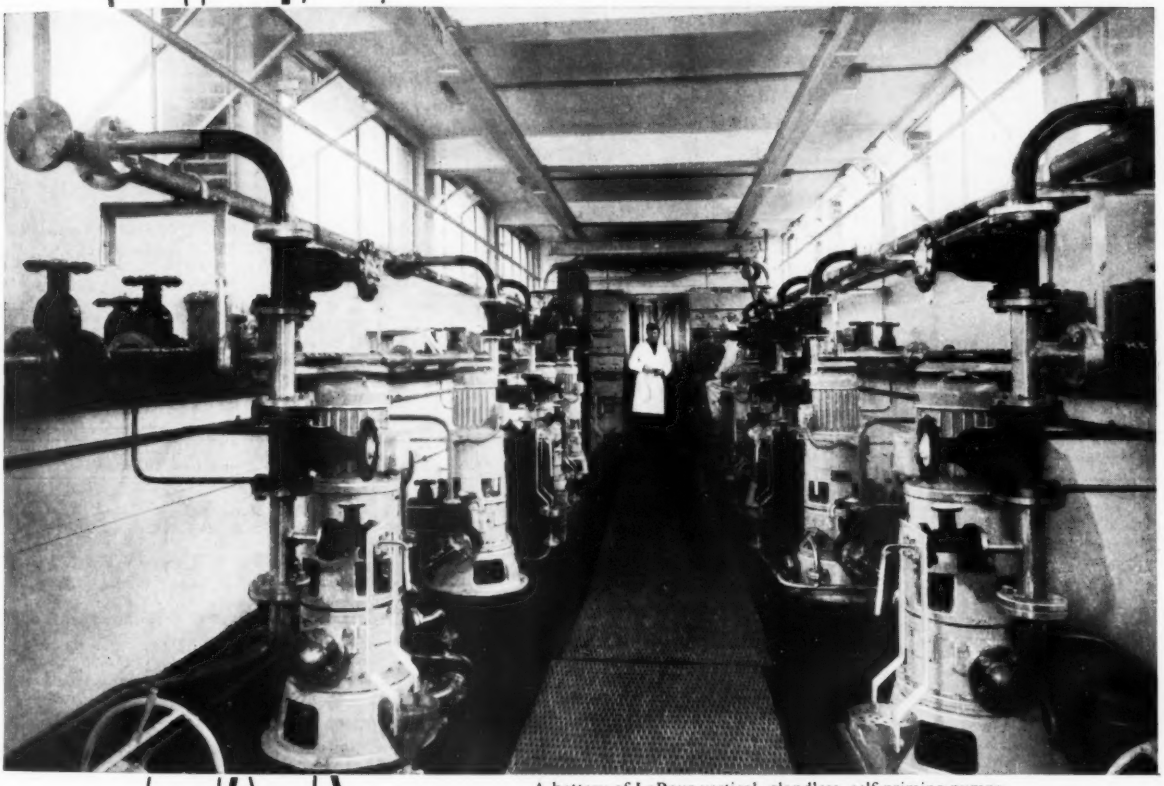
For further information on the above service and our standard products please contact the TECHNICAL SALES OFFICE

M.B. METALS LTD.

VALE WORKS, PORTSLADE, SUSSEX
TELEPHONE: HOVE 46275

APPROVED BY

UNITED KINGDOM ATOMIC ENERGY AUTHORITY



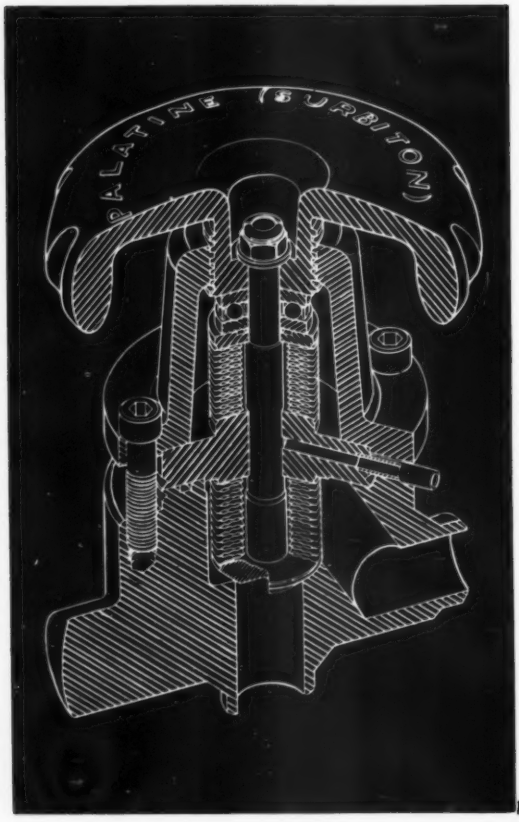
A battery of LaBour vertical, glandless, self-priming pumps.
(Photograph by courtesy of the United Kingdom Atomic Energy Authority)

More than 250 LaBour pumps have been installed at one establishment alone of the U.K.A.E.A. Whether it is liquors or slurries, chemicals or effluents, mine dewatering etc., experienced engineers repeatedly specify LaBour pumps. They know that the simple, one-moving-part design assures uninterrupted service, long life and reduced maintenance. They appreciate the 'extra' features that LaBour pumps have—extra thick sections and extra heavy bearings which mean rigidity; the extra deep stuffing box; and the extra special materials which give extra resistance to corrosion and erosion.

LABOUR

BRITISH LABOUR PUMP CO. LTD. BLUNDELL ST. LONDON N7 TEL: NORTH 6601-5

P2320



POSITIVELY SEALED GLANDLESS VALVES

Suitable for a wide variety of liquids and gases Toxic—Radioactive—Corrosive or Explosive.

- ROBUST & COMPACT
- POSITIVE METALLIC BELLOWS SEALING
- EASY CONTROL
- MINIMUM OPERATING EFFORT
- FORGED LEAKPROOF BODIES
- HARD FACED POPPET OR DISC INSERTS

Palatine design and supply a wide variety of Valves to U.K.A.E.A. at Capenhurst, Aldermaston, Harwell, etc. and to the Chemical and Petroleum Industries.

REMOTE CONTROL VALVES OPERATED BY AIR DIAPHRAGM OR PNEUMATIC MOTORS—ELECTRIC ACTUATORS—VERY COMPACT HIGH TEMPERATURE —VACUUM—LIQUID VALVES. PORTING AND STUBS TO CUSTOMER'S REQUIREMENTS.

PALATINE (SURBITON) LIMITED

64/76 BRIGHTON ROAD · SURBITON · SURREY
TELEPHONE ELMBRIDGE 7261-3

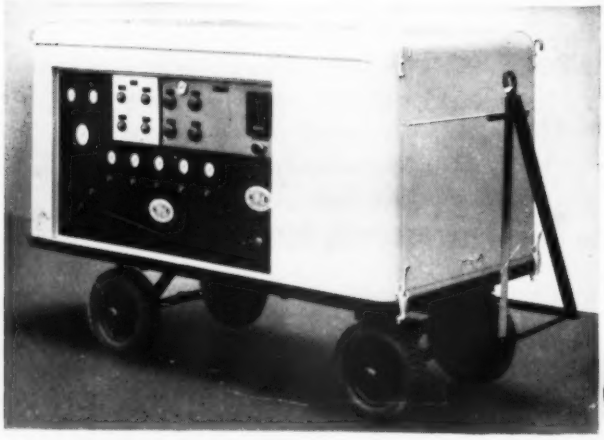
W&J

3 STAGE Air or Nitrogen COMPRESSOR SETS

These self-contained units have a displacement of 9.8 cu. ft. per minute at working pressures up to a maximum of 6000 lb/sq. inch.

Supplied for ground servicing the hydraulic equipment or servo mechanism on the following aircraft:—Bristol Britannia, Vickers Viscount, Fokker Friendship, Military Aircraft (S.R. 53 and Gloster Javelin) and Guided Missiles. In addition they are used for a wide variety of industrial applications.

Please write for Leaflet No. 19 giving full details.



WILLIAMS & JAMES (ENGINEERS) LIMITED
GLOUCESTER ENGLAND
TELEPHONE · GLOUCESTER 24021-2-3 · TELEGRAMS & CABLES: "COMPRESSOR GLOUCESTER"

n
S
of
a
lic
w-
nt,
53
In
of
19
ls.
960

SERVICE DE RENSEIGNEMENTS POUR NOS LECTEURS

Il est souvent difficile au client publicitaire d'indiquer dans un espace restreint tous les détails de ses produits. Dans le cas où vous désireriez de plus amples renseignements à ce sujet, veuillez pointer le numéro approprié sur la carte ci-contre et envoyer cette dernière à NUCLEAR POWER

AUSKUNFTSDIENST FÜR LESER

Es ist oft schwierig für Inserenten alle technischen Einzelheiten über ihre Produkte in einem begrenzten Platz zu bringen. Sollten Sie noch weitere Auskünfte wünschen, streichen Sie einfach die bestimmten Nummern auf der nebenstehenden Karte an, und senden Sie sie an NUCLEAR POWER

SERVIZIO D'INFORMAZIONI PER I NOSTRI LETTORI

E' talvolta difficile all'inserzionista di indicare in uno spazio ristretto tutti i particolari dei suoi prodotti. Qualora desiderate ricevere più ampie informazioni a questo riguardo, favorite segnare il numero appropriato sul cartellino qui accanto ed inviare quest'ultimo a NUCLEAR POWER

SERVICIO DE INFORMACIÓN PARA EL LECTOR

Se hace a menudo difícil para los anunciantes dar en un espacio limitado todos los detalles técnicos sobre sus productos. Si desea ulterior información, marque los números apropiados en la tarjeta opuesta y mándela a NUCLEAR POWER

Информация для читателей

Часто бывает трудно рекламирующим лицам давать все технические подробности своей продукции в рекламе. Если Вам понадобятся добавочные сведения, то просто отметьте соответствующие номера на карточке на противоположной стороне и отправьте к NUCLEAR POWER

讀者詢問服務

在廣告上以有限的地方來解釋一般專門技術及它們的功能，的確是有受限制的困難。若讀者欲要知道一些詳細的情形就請將讀者問卷的表格取一號下來照圈下有關問的項目，同笔勾一下寄校子能工經最即可。

読者サービス

廣告紙面の関係上、製品の技術的細目は掲載しきれません。ので詳しくは貴のカードの適當なナンバーに印をつけて廣子が発送して下さればお答へします

Nuclear Power

REACTORS MATERIALS INSTRUMENTATION PROCESSES IRRADIATION

READER INFORMATION SERVICE **April 1960**

Advertisements

1	24	47	70	93	116	139	162	185
2	25	48	71	94	117	140	163	186
3	26	49	72	95	118	141	164	187
4	27	50	73	96	119	142	165	188
5	28	51	74	97	120	143	166	189
6	29	52	75	98	121	144	167	190
7	30	53	76	99	122	145	168	191
8	31	54	77	100	123	146	169	192
9	32	55	78	101	124	147	170	193
10	33	56	79	102	125	148	171	194
11	34	57	80	103	126	149	172	195
12	35	58	81	104	127	150	173	196
13	36	59	82	105	128	151	174	197
14	37	60	83	106	129	152	175	198
15	38	61	84	107	130	153	176	199
16	39	62	85	108	131	154	177	200
17	40	63	86	109	132	155	178	201
18	41	64	87	110	133	156	179	202
19	42	65	88	111	134	157	180	203
20	43	66	89	112	135	158	181	204
21	44	67	90	113	136	159	182	205
22	45	68	91	114	137	160	183	206
23	46	69	92	115	138	161	184	207

New Products and Tech. Literature

208	214	220	226	232	238	244	250	256
209	215	221	227	233	239	245	251	257
210	216	222	228	234	240	246	252	258
211	217	223	229	235	241	247	253	259
212	218	224	230	236	242	248	254	260
213	219	225	231	237	243	249	255	261

Books

262	264	266	268	270	272	274	276	278
263	265	267	269	271	273	275	277	279

If you would like further information about any advertisement or editorial item, simply tick the appropriate numbers on this card and mail to NUCLEAR POWER.

NAME

NAME OF BUSINESS

ADDRESS

POSITION HELD

NATURE OF BUSINESS

Nuclear Power

REACTORS MATERIALS INSTRUMENTATION PROCESSES IRRADIATION

READER INFORMATION SERVICE **April 1960**

Advertisements

1	24	47	70	93	116	139	162	185
2	25	48	71	94	117	140	163	186
3	26	49	72	95	118	141	164	187
4	27	50	73	96	119	142	165	188
5	28	51	74	97	120	143	166	189
6	29	52	75	98	121	144	167	190
7	30	53	76	99	122	145	168	191
8	31	54	77	100	123	146	169	192
9	32	55	78	101	124	147	170	193
10	33	56	79	102	125	148	171	194
11	34	57	80	103	126	149	172	195
12	35	58	81	104	127	150	173	196
13	36	59	82	105	128	151	174	197
14	37	60	83	106	129	152	175	198
15	38	61	84	107	130	153	176	199
16	39	62	85	108	131	154	177	200
17	40	63	86	109	132	155	178	201
18	41	64	87	110	133	156	179	202
19	42	65	88	111	134	157	180	203
20	43	66	89	112	135	158	181	204
21	44	67	90	113	136	159	182	205
22	45	68	91	114	137	160	183	206
23	46	69	92	115	138	161	184	207

New Products and Tech. Literature

208	214	220	226	232	238	244	250	256
209	215	221	227	233	239	245	251	257
210	216	222	228	234	240	246	252	258
211	217	223	229	235	241	247	253	259
212	218	224	230	236	242	248	254	260
213	219	225	231	237	243	249	255	261

Books

262	264	266	268	270	272	274	276	278
263	265	267	269	271	273	275	277	279

If you would like further information about any advertisement or editorial item, simply tick the appropriate numbers on this card and mail to NUCLEAR POWER.

NAME

NAME OF BUSINESS

ADDRESS

POSITION HELD

NATURE OF BUSINESS

Nuclear Power

REACTORS MATERIALS INSTRUMENTATION PROCESSES IRRADIATION

READER INFORMATION SERVICE **April 1960**

Advertisements

1	24	47	70	93	116	139	162	185
2	25	48	71	94	117	140	163	186
3	26	49	72	95	118	141	164	187
4	27	50	73	96	119	142	165	188
5	28	51	74	97	120	143	166	189
6	29	52	75	98	121	144	167	190
7	30	53	76	99	122	145	168	191
8	31	54	77	100	123	146	169	192
9	32	55	78	101	124	147	170	193
10	33	56	79	102	125	148	171	194
11	34	57	80	103	126	149	172	195
12	35	58	81	104	127	150	173	196
13	36	59	82	105	128	151	174	197
14	37	60	83	106	129	152	175	198
15	38	61	84	107	130	153	176	199
16	39	62	85	108	131	154	177	200
17	40	63	86	109	132	155	178	201
18	41	64	87	110	133	156	179	202
19	42	65	88	111	134	157	180	203
20	43	66	89	112	135	158	181	204
21	44	67	90	113	136	159	182	205
22	45	68	91	114	137	160	183	206
23	46	69	92	115	138	161	184	207

New Products and Tech. Literature

208	214	220	226	232	238	244	250	256
209	215	221	227	233	239	245	251	257
210	216	222	228	234	240	246	252	258
211	217	223	229	235	241	247	253	259
212	218	224	230	236	242	248	254	260
213	219	225	231	237	243	249	255	261

Books

If you would like further information about any advertisement or editorial item, simply tick the appropriate numbers on this card and mail to NUCLEAR POWER.

NAME

NAME OF BUSINESS

ADDRESS

POSITION HELD

NATURE OF BUSINESS

Postage will be paid by Nuclear Power

No Postage stamp necessary if posted in Great Britain or Northern Ireland

Business Reply Folder Licence WD 1823

NUCLEAR POWER
Rowse Muir Publications Ltd,
The Rowse Muir Building,
77–79 Charlotte Street,
London, W1
England

Postage will be paid by Nuclear Power

No Postage stamp necessary if posted in Great Britain or Northern Ireland

Business Reply Folder Licence WD 1823

NUCLEAR POWER
Rowse Muir Publications Ltd,
The Rowse Muir Building,
77–79 Charlotte Street,
London, W1
England

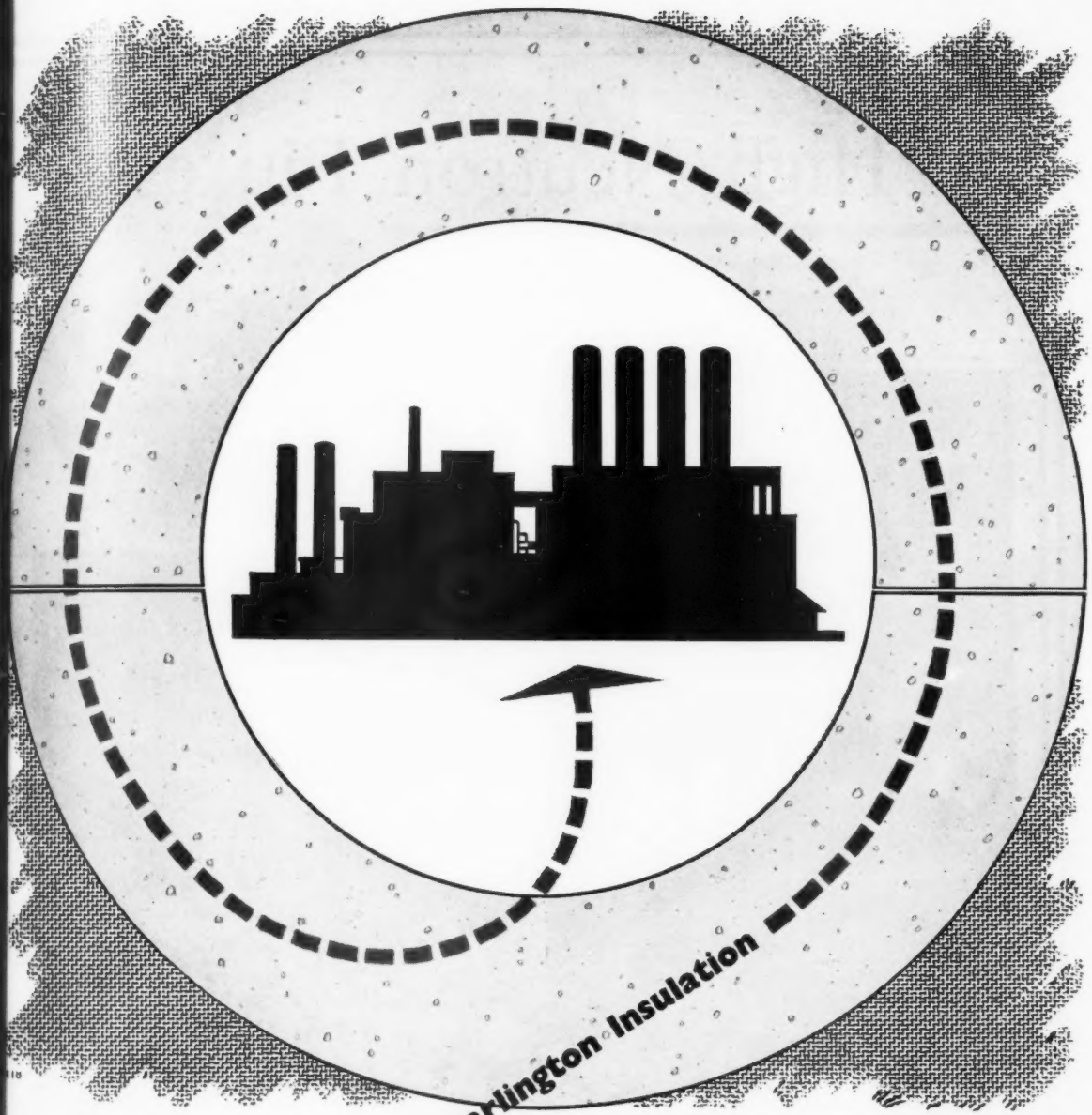
Postage will be paid by Nuclear Power

No Postage stamp necessary if posted in Great Britain or Northern Ireland

Business Reply Folder Licence WD 1823

NUCLEAR POWER
Rowse Muir Publications Ltd,
The Rowse Muir Building,
77–79 Charlotte Street,
London, W1
England

WITHDRAWN



Year after year the Central Electricity Generating Board's list of power stations with the highest operating efficiencies includes a majority of stations where the efficiency is guarded by Darlington Insulation. In the 1957 list, for example, the top four stations are Darlington insulated.
Coincidence ? Not a bit of it ! Just skill and years of experience, plus careful specifications and the right materials.
It's The Darlington Insulation Company's job to help maintain high thermal efficiencies, and they do it very well.

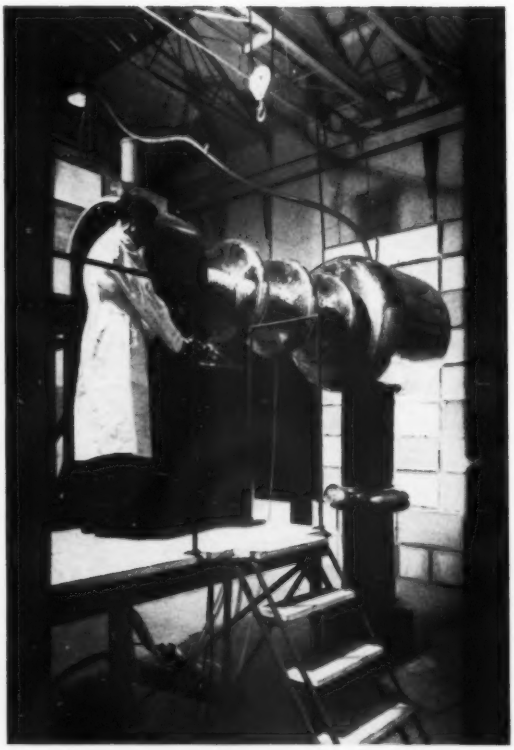
THE DARLINGTON INSULATION CO. LTD

38 Great North Road, Newcastle upon Tyne, 2
and branch offices at London, Birmingham, Bolton, Bristol, Cardiff, Glasgow, Leicester and Sheffield.

A Member of The Darlington Group of Companies

Tick **No 165** on reply card for further details

High Neutron Fluxes
at low cost



600 KV Neutron Generator, type "S" giving an output greater than 10^{12} neutrons/second, with a pulsed or continuous beam.

The high voltage is generated by a standard electrostatic generator delivering 600 KV at 4 mAs.

1 MeV prototype electrostatic generator being assembled at Grenoble. This machine is to be used in conjunction with a very high power neutron generator with an output considerably in excess of type "S".

A full range of smaller neutron generators is available

S.A.M.E.S. s.a., GRENOBLE, FRANCE

SOLE REPRESENTATIVES U.K. AND COMMONWEALTH

MILES HIVOLT LTD., SHOREHAM AIRPORT

SHOREHAM-BY-SEA, SUSSEX

Telephone: HOVE 70266

Tick **No 167** on reply card for further details

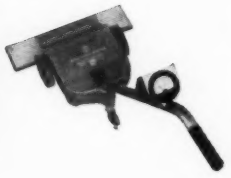
new advancements in NUCLEONICS from U. S. A.

Frazar & Hansen Ltd., internationally known since 1834, presents many leading U.S.A. manufactured nuclear instruments and components, including monitors and detectors, radio-chemical analysis equipment, nuclear medical scanners, educational teaching aids and radiation shielding and protective equipment. **Write for information.**

Single Channel Remote Area Monitor

Model GA Series. Available in the GA-3 series with 2-point electronic calibration in the GA-4 series with the same and with the addition of "source check" feature, and in the GA-5 series with 2-point source (SR-90) calibration only. The GA series offers any continuous combination 3 decade logarithmic ranges from ·01 mr/hr to 100,000 R/hr. Energy dependence is flat to within plus or minus 10% from 80 KV to 1·2 Mev.

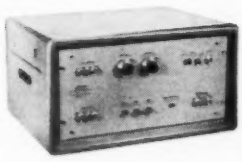
RIGGS NUCLEONICS



Alpha Floor Monitor

Model FM-3G. Designed to enhance the surveying of floor surfaces of research, operation, or production areas where alpha-emitting radioactive materials are present. Its high sensitivity, large area probe searches out hidden alpha contamination not readily detectable with ordinary portable alpha survey instrumentation. Eliminates delays involved in "smear or wipe" techniques. Well balanced and self-contained. 2 pi geometry meter readout determines immediately the contamination status of an area.

EBERLINE INSTRUMENT CORP.



Coincidence Radiation Analyzer

Model 704. Measurement of minute quantities of radioactive material is enhanced by coincidence analysis. By counting only simultaneous pulses, background virtually eliminated. Used with a wide selection of single channel analyzers, linear amplifiers. It employs delay line compensation for transit time of single channel analyzers used in a coincidence experiment. Delay lines easily modified to suit transit time of the particular single channel analyzer in use.

INTERSTATE ELECTRONICS CORP.

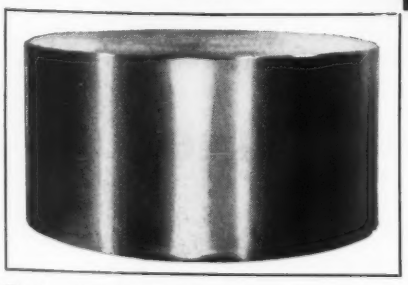
FRAZAR & HANSEN Ltd., 301 Clay Street, San Francisco, Calif., U.S.A.

G.E.C.

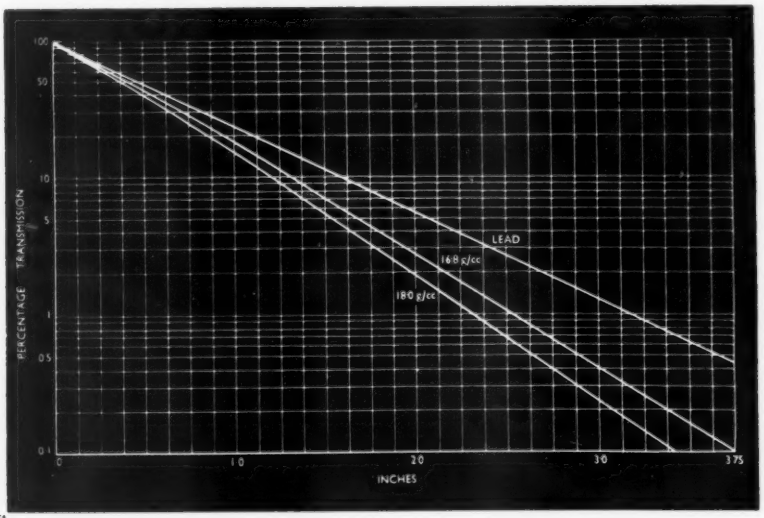
HEAVY ALLOY

supplied in densities
16.8,17.0,17.5,18.0g/cc(nominal)

- ***for screening purposes***
- ***for balance weights***



The above piece of G.E.C. Heavy Alloy was made for the United Kingdom Atomic Energy Authority. It weighs 660 lb.



Broad beam absorption of Gamma-radiation from COBALT-60. Density: 16·8 g/cc. and 18·0 g/cc.

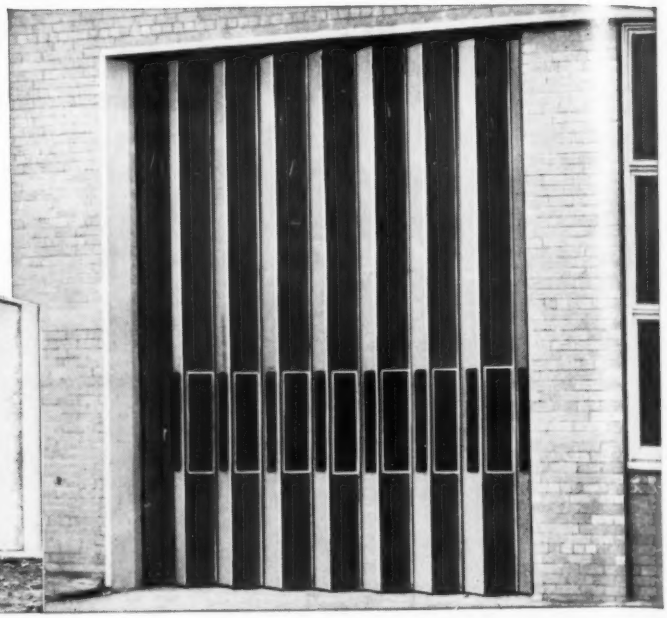
THE GENERAL ELECTRIC CO. LTD., Component Sales Dept., Osram Metals, East Lane, Wembley, Middlesex. Arnold 4321

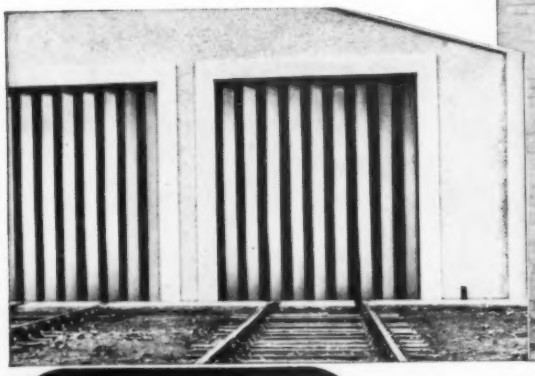
Tick **No 169** on reply card for further details

BOLTON Patent Shutter Doors

Custom built to your requirements

Available with continuous glazing, as shown on right, Bolton Shutter Doors readily accommodate all special requirements from railway track clearance, as shown below, to overhead cables and runway beams. May we send you our latest catalogue, reference 346?





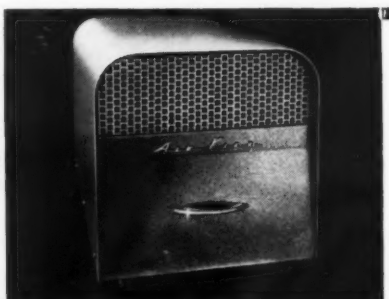
BOLTON *The BIG name in doors*

BOLTON GATE CO LTD
BOLTON · LANCASHIRE

Branches at: Belfast, Birmingham, Bristol, Dublin, Liverpool, London, Manchester, Newcastle upon Tyne

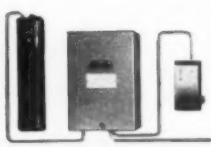
BG346

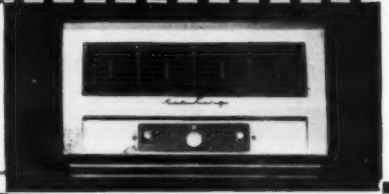
temperature control and air conditioning in industry



THE 'AIR KING' PORTABLE DE HUMIDIFIER

Efficiently safeguards property and products from damp air by eliminating mould, mildew, rust, decay and warpage. Modern in appearance, economic in operation, compact and portable.





THE 'AIR KING' STATIC UNIT

An efficient, easy to install, most attractive air-conditioning unit for Offices, Stores, Standards rooms, Laboratories etc., - in fact, everywhere that cool, clean air is essential. Beautifully styled, superbly made.

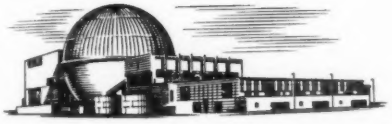
AirKing

AIR CONDITIONING UNITS

Direct your enquiries to **B. O. MORRIS LTD., BRITON ROAD, COVENTRY. Tel: 53333 (PBX)**

BY APPOINTMENT TO HER MAJESTY THE QUEEN
Suppliers of Fire Extinguishers *The Pyrene Company Limited*

facing new industrial fire problems



The Pyrene Company, with its unrivalled facilities for research, keeps ahead of changing industrial techniques, and is constantly developing the means to overcome the new fire risks they involve. As makers of the world's most comprehensive range of fire-fighting equipment, The Pyrene Company can give you invaluable and impartial advice on any fire protection problem—it is yours for the asking. We are proud to have given advice on fire protection—and supplied major fire-fighting equipment—for most British atomic centres already constructed. This service is also being applied to many new engineering plants and production methods used in modern industry. Consult Pyrene Fire Engineers and ensure maximum fire protection for valuable plant and human lives too.

Pyrene TRADE MARK FIRE APPLIANCES

protect
ALDERMASTON
CALDER HALL
CAPENHURST
DOUNREAY · FOULNESS
HARWELL · SPRINGFIELD
WINDSCALE

Pyrene TRADE MARK FIRE FIGHTING EQUIPMENT

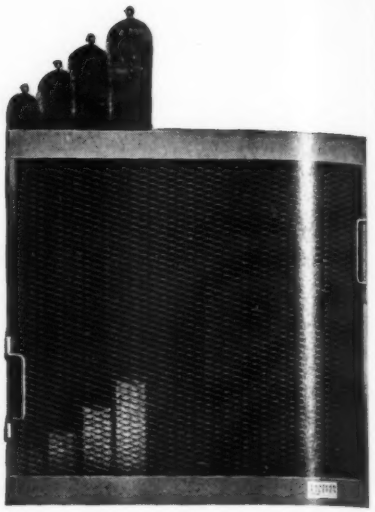
THE PYRENE COMPANY LIMITED

(Dept. NP 4) GROSVENOR GARDENS · LONDON S.W.1 *Tel:* VICtoria 3401
Head Office & Works: GREAT WEST ROAD · BRENTFORD · MIDDX
Canadian Plant: TORONTO *Australian Plant:* MELBOURNE

Tick **No 171** on reply card for further details

YOU DON'T NEED SPECIAL EQUIPMENT OR FLUIDS TO CLEAN THIS AIR FILTER!

Heather Multi-Brush Air Filters can be cleaned easily and thoroughly, without special equipment or fluids, and still retain the initial filtering efficiency. In fact, maximum efficiency and minimum maintenance is the correct way to sum up this unique, low-cost filter system.



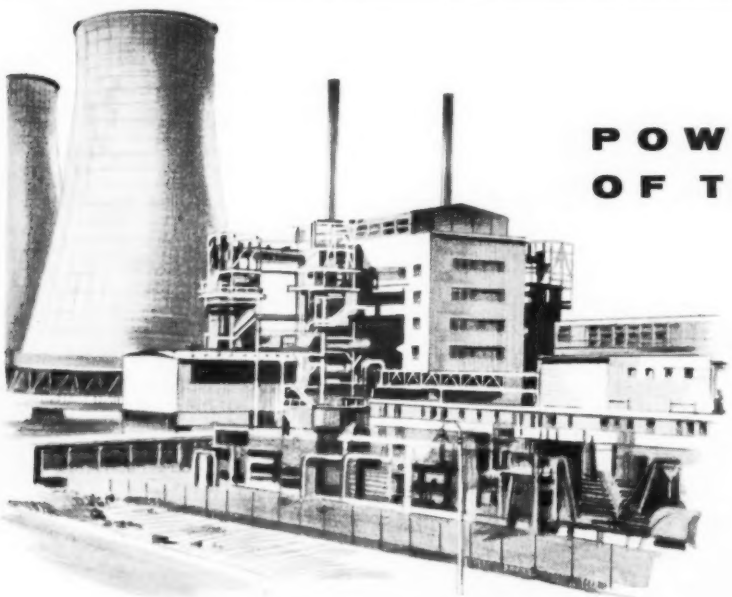
A finely graded mesh of intermingling hair, specially selected to withstand the varying humidity and conditions of the dust-laden air, is used to trap impurities and dust particles from the incoming air stream. Periodically, the filter brushes can be cleaned simply by shaking or suction cleaning.

** Write NOW for leaflet 'H39' which gives full details.*

HEATHER FILTERS LIMITED

7 KENDALL PLACE . BAKER STREET . LONDON W.I HUNTER 1801

H.F.



Calder Hall Atomic Power Station

POWER STATIONS OF THE NEW AGE

The economy, safety and long life of Staveley cast iron pipes need little more recommendation than their use under the trying technical conditions of Britain's nuclear power stations.

Whether carrying water, wastes or gas, Staveley pipes have withstood the test of years and benefited from every forward step in cast iron metallurgy and manufacturing practice.

STAVELEY CAST IRON PIPES

Telephone: Chesterfield 7251 THE STAVELEY IRON & CHEMICAL CO. LTD., NR. CHESTERFIELD.

For

*HEAT-RESISTANT CONCRETE

WITH SPECIAL PROPERTIES
FOR SPECIAL PROBLEMS

Exceptional cold strength at 24 hours and permanent residual strength for structural purposes at elevated temperatures.

Great thermal shock resistance.
Volume stability at temperature.
Low thermal conductivity.
Highly resistant to chemical attack.

Shielding action at elevated temperatures due to high proportion of combined water.

(*Temperature limit up to 1350°C, dependent on type of heat-resistant aggregate employed !)

Our Technical Dept. is entirely at your disposal for further specific information

FOR SPEED—STRENGTH

RESISTANCE

REFRACTORINESS

Manufactured by
LAFARGE ALUMINOUS CEMENT COMPANY LTD
73, Brook Street, London, W.1 Tel: MAY 8546

For operating temperatures up to 1800°C, or when a refractory resistant to reducing conditions is required, use Super-Duty Refractory Concretes made with SECAR 250, a pure white calcium-aluminate cement, free from iron oxides. Write for details.

AP/22

Tick **No 175** on reply card for further details

WESTON

MOVING COIL

RELAYS

The simplicity and reliability of relay control for a wide variety of applications has led to the ever increasing use of Weston Moving Coil Relays. Let us have a note of your relay problems and we will be pleased to advise on the most suitable model for any set of conditions. Enquiries should, if possible, be accompanied by full particulars of both control and local circuits.

Illustrated is the Model S170. Other types include the Model S124, a magnetic contact relay which operates with a minimum power input of 0.004 microwatt and the Model S115, a miniature relay, which functions as an "on-off" switching relay.

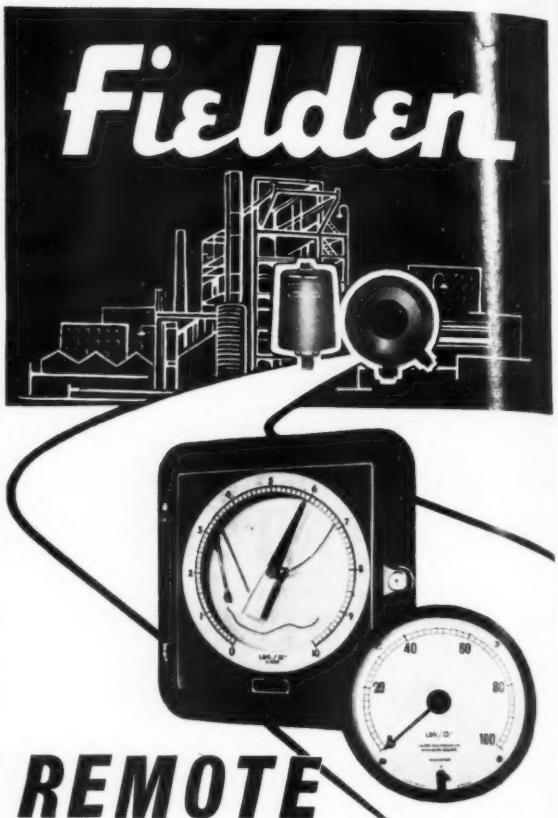
SANGAMO WESTON LIMITED
ENFIELD · MIDDLESEX
Tel: ENField 3434 (6 lines) & 1242 (6 lines) Grams: Sanwest, Enfield

Scottish Factory: Port Glasgow, Renfrewshire, Port Glasgow 41151
Branches: London, CHAncery 4971 · Glasgow, Central 6208 · Manchester, Central 7904 Newcastle-upon-Tyne, Newcastle 26867 · Leeds, Leeds 30867 · Liverpool, Central 0230 Wolverhampton, Wolverhampton 21912 · Nottingham, Nottingham 42403 · Bristol, Bristol 21781 · Southampton, Southampton 23328.

SW/67

Tick **No 176** on reply card for fu[illegible]er details

Fielden



REMOTE PRESSURE

INDICATING · RECORDING · CONTROLLING

FOR . . .

Steam and other gases.

Water, oil and other liquids.

Pressures down to 5" wg and up to 15000 p.s.i.

Indicating, recording or controlling or any combination of these features.

Vacuum, absolute and differential pressures as well as the usual gauge pressures.

Transmission over distances of a few feet or hundreds of yards.

WITH . . .

Accuracies as high as 0·5%.

Immediate response at the receiving instrument to changes in pressure at the measuring point.

Robust but simple wiring between the transmitter and the indicating recording or controlling instrument.

Intrinsic safety certificate.

Wide range of indicating meters in many sizes, recorders for wall and panel mounting, controllers for electrical and pneumatic control etc.

★ *Write for Remote Pressure brochure NP.*

Fielden

FIELDEN ELECTRONICS LIMITED · WYTHENSHAWE · MANCHESTER
'Phone: Wythenshawe 3251 · 'Grams: Humidity Manchester
also AUSTRALIA, ITALY and CANADA.

Branch Offices: LONDON, WALSALL, STOCKTON-ON-TEES, EDINBURGH and DUBLIN
Agents throughout the world

Indicating Recording Control

sensitive
pressure
responsive
elements

for . . .

NUCLEAR AND CHEMICAL PROCESS CONTROL SYSTEMS — MISSILE AND AIRCRAFT APPLICATIONS — INDUSTRIAL METERS — FLOW-TANK CONTENTS — REMOTE AND DIRECT READING PRESSURE AND VACUUM GAUGES — SPECIALISED APPLICATIONS.

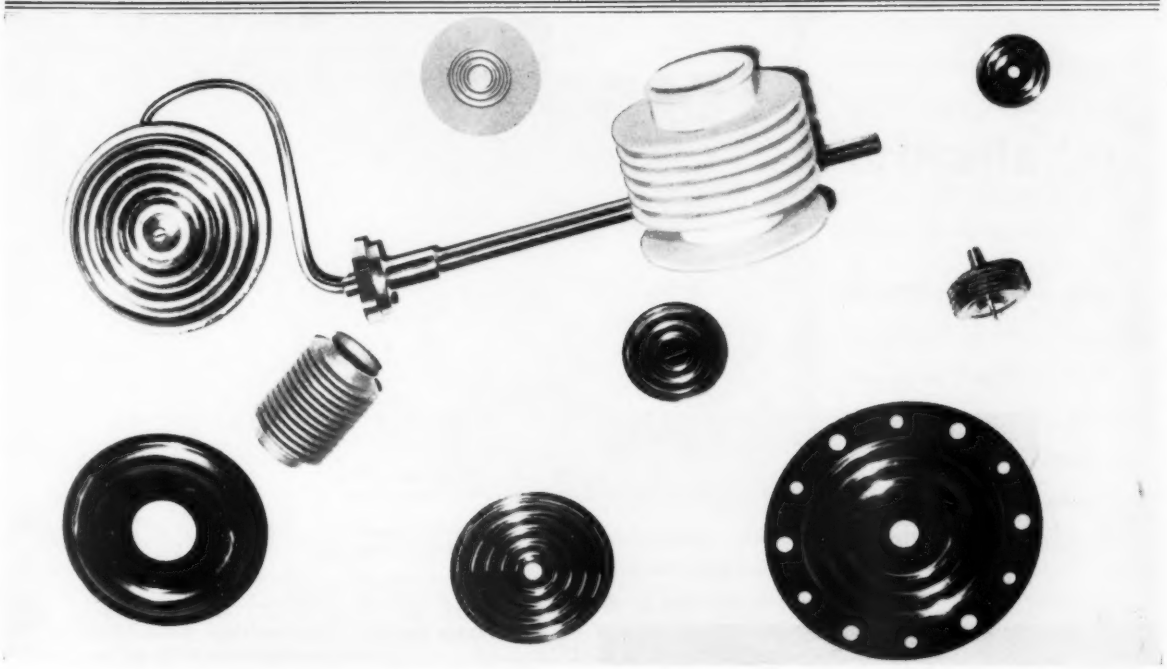
CAPSULES, DIAPHRAGMS AND BELLOWS. Available in Phosphor Bronze, Beryllium Copper, Ni-Span ' C ', Stainless Steel, Monel, ' K ' Monel, Inconel, and P.T.F.E., cover a very wide range of sizes and performance.

Appleby & Ireland Limited Cordially invite you to make full use of the special facilities and long experience which we place at your disposal for Research, Development and Production.

Send for Further Information from:

APPLEBY & IRELAND LIMITED

BASINGSTOKE, HAMPSHIRE. TELEPHONE: BASINGSTOKE 2510/3
Telex: 8546 Cables: Apland, Basingstoke



Tick **No. 178** on reply card for further details

UKAEA
ENQUIRIES INVITED

S.M.P

PRECISION ENGINEERS

BRIEF PARTICULARS OF PLANT INSTALLED

LATHES: Capstan, Screw Cutting, Special Purpose.
MILLING MACHINES: Plain, Universal, Vertical, Special Purpose.
DRILLING MACHINES: Radial, Sensitive, Multi Spindle, Tapping.
GRINDING MACHINES: Plain, Universal, Surface, Internal.
BORING MACHINES: Single Spindle, Double Ended.
BROACHING MACHINES
AUTO SCREW MACHINES: Single Spindle up to 2¼" dia. Multi Spindle up to 2¼" dia.
PRESSES: Up to 100 ton.

Stove Enamelling, Assembly, Linishing, Roto Finish, Plating, and Hardening Shops, including H.F. Hardening

TOOLROOM, EXPERIMENTAL DEPARTMENT, AND OWN DESIGN AND DRAWING OFFICE.

Approved A.I.D., D.I.Arm., A.R.B. and also Approved tenderers to the U.K.A.E.A.

★ We are machining specialists in stainless and various high tensile steels.

SCREW MACHINE PRODUCTS LTD.
Wooburn Green, Nr. High Wycombe, Bucks.
Telephone: Bourne End 1444/8 (5 lines)

Tick **No 179** on reply card for further details

[redacted]

for protection against radiation

look ahead with LEAD

not forgetting, LEAD GLASS

[redacted]

The technical officers of the Association are always glad to give individual assistance.
LEAD DEVELOPMENT ASSOCIATION, 18 Adam Street, London, W.C.2.
Telephone: WHitehall 4175 Telegrams: Leadevep, Rand, London

[redacted]

LDA1/60

Tick **No 180** on reply card for further details

D. A. E. P.

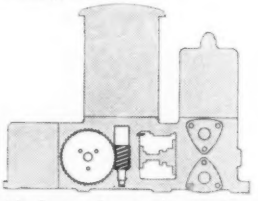
DOUBLE ACTING ENCLOSED WORM DRIVE PUMP

Suitable for:—Boiler Feed, Seawater, Fuel oil and viscous fluids up to 3,500 sec. Redwood I

EFFICIENCY *Duty/Power High Ratio*
1700 G.P.H./200 P.S.I. — 7½ H.P.
to
57 G.P.H./150 P.S.I. — ¼ H.P.

ECONOMY Low current — requiring simple, inexpensive switchgear.

TROUBLE-FREE LONG LIFE WORM DRIVE



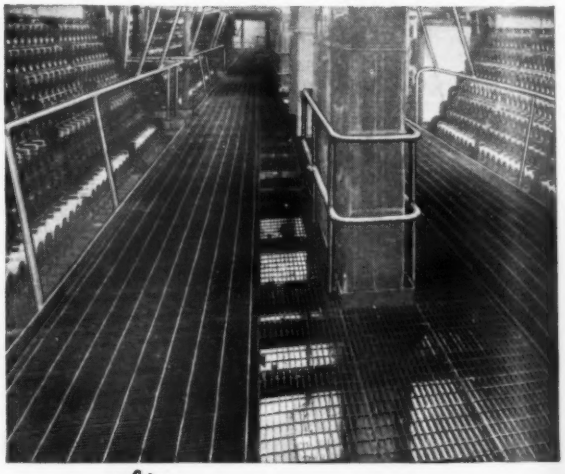
SEPARATE UNITS Individual gear box and pumping unit are bolted together. IRON, GUNMETAL or STAINLESS STEEL Pumps do not therefore have to have the gear box in these expensive metals.

Suitable for all climatic conditions

Write for details to the manufacturers:

RICHARD GROSVENOR & CO. LTD.
53-54 VICTORIA ROAD, SURBITON, SURREY
Telephone: Elmbridge 7700-1

Tick **No 181** on reply card for further details



Non-Slip **MECHANICALLY LOCKED No. 3 Type**

OPEN STEEL FLOORING

Ideal for factories, warehouses, refineries, gas works, fire escapes, etc.
Supplied with handrails and standards if desired.

by Bettles

Our technical staff will be pleased to assist you

BETTLES & SONS LTD., ARCWEL FACTORY
STAFFORD ROAD, FORDHOUSES, WOLVERHAMPTON
Telephone: Fordhouses 2278-9

Downeay Submarine Project

We are proud to be able to announce that on behalf of Admiralty we have been favoured with an order from Messrs Foster Wheeler Ltd for an appreciable number of small bore High Pressure Valves for the Dounreay Submarine Project. These Valves have been specially designed by us to meet the exacting conditions which will exist in the first of Her Majesty's Submarines to be driven by Atomic Machinery of wholly British Manufacture.

Sydney Smith & Sons (Nottingham) Ltd

CRYSTAL PHOSPHORS

Hilger & Watts crystal phosphors are highly efficient in detecting and resolving X-rays and gamma-rays. and so are well suited for use in pulse-height analysers. We grow them from very pure melts of thallium-activated sodium iodide, and their potassium content is negligible.

We make a standard range of crystals, whose sizes range from ½ in. in diameter and ½ in. thick, to 4½ in. in diameter and 2 in. thick. The crystals are mounted in metal containers, which are lined with magnesium to increase their light output.

HILGER & WATTS

HILGER & WATTS LIMITED 98 ST PANCRAS WAY LONDON NW1 *Tel: GULliver 5636*

Tick **No 184** on reply card for further details

Visit Stand
S. 871
National Gallery
23 - 28 May
I.E.A. Exhibition
OLYMPIA

Apply ELECTROLUBE lubricants to all SWITCH CONTACTS and BEARING SURFACES of turret tuners, plugs and sockets, controls, gram motors, tape recorders etc.

ELECTROLUBE lubricants are a British discovery—a scientific preparation—not "just another switch cleaner".

ELECTROLUBE lubricants stay effective for months.

Make contact with *Electrolube*

BRAND
LUBRICANT

ELECTROLUBE Brand No. 1 for light current applications, reduces fixed and relay contact resistance, stops audio interference, increases h.f. and l.f. gain by 3 dB etc.

ELECTROLUBE Brand No. 2 for sparking contacts and heavier current duties, operates under difficult conditions, reduces wear on contactors 3 to 5 times; increases life of battery motors 8 times.

Available in New
NYLON
SNORKEL Container

No. 1 22/- nett trade
No. 2 33/- nett trade

Supplies Only Through Your Wholesaler

Electrolube and Snorkel are Registered Trade Marks of ELECTROLUBE LTD. 16, Berkeley Street, London, W.1. 24 hour ANSAFONE service. Tel. HYDE Park 0501 (5 lines)

Tick **No 185** on reply card for further details

laboratory end runner mills

Available with four mortar sizes, 7", 10", 15", 20". Mill supplied complete with electric motor and starter and with either ceramic or metal mortar and pestle.

The mortars and pestles are interchangeable. A ceramic set can be used to process material adversely affected by contact with metal and a metal set, either high grade cast iron or stainless iron can be carried as a spare set for use on material for which ceramic is unsuitable. The pestles are arranged to swing clear of or lift out of the mortars to facilitate emptying or cleaning.

The model illustrated is the No.2 mill with a 15" diameter mortar

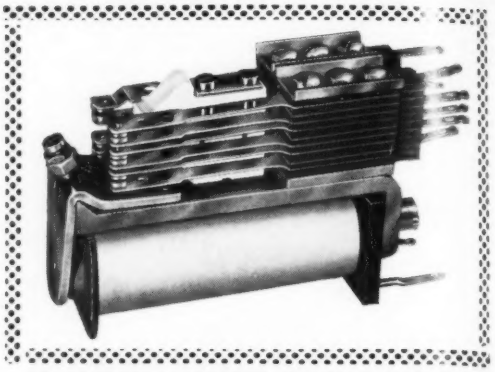
PASCALL

Write or telephone Crawley 25166 for List EN 3204.

THE PASCALL ENGINEERING CO. LTD.
GATWICK ROAD · CRAWLEY · SUSSEX.

Tick **No 186** on reply card for further details

RELAYS
TO SPECIFICATION



POST OFFICE TYPE
3,000 and 600 RELAYS

Specialists in tropical and Services jungle finish.
Guaranteed to full A.I.D. and I.E.M.E. standards.
Prompt Deliveries Prototypes within 24 hours.
Post Office approved. All relays guaranteed made in our own works.
P.T.F.E. insulation now available.

SIMMONDS

Manufacturers to H.M. Government Departments and leading Contractors
L. E. SIMMONDS LIMITED, 5 BYRON ROAD, HARROW, MIDDX.
TELEPHONE: HARROW 7797/9 TELEGRAMS: SIMRELAY HARROW

Tick **No 187** on reply card for further details

ENDECOTTS
TEST SIEVES
For Accuracy!

POCKET INTERCHANGER SIEVES

'ENDROCK' TEST SIEVE SHAKER

TEST SIEVES
B.S. 410: 43 U.S. Standards
and Tyler Equivalents

We operate a Recovering Service

Consistent mechanical action—
saves valuable time of skilled personnel

ENDECOTTS (FILTERS) LTD.
Dept. A. Lombard Road, London, S.W.19.
Phone: **LIBerty 8121/2/3**
Grams: **Endfilt, London**

CLASSIFIED ADVERTISEMENTS

DISPLAY ANNOUNCEMENT RATES :— 1 insertion 50/- per single col. inch
6 insertions 47/6 per single col. inch
12 insertions 45/- per single col. inch

LINEAGE ANNOUNCEMENT RATES :— 5/- per line. 5% discount 6 insertions, 10% discount 12 insertions

BOX Nos. :— 1/- extra will be charged

COPY DATE :— Advertisements for May issue to be received not later than April 4th

SITUATIONS VACANT

Assistant Chief Engineers

SALARIES

will be between £2,400 and £2,900 according to qualifications and experience.
Contributory Superannuation.
Housing will be available.

APPLICATIONS

Write for application form, quoting appropriate reference number, to: Group Recruitment Officer,

DEVELOPMENT AND ENGINEERING GROUP,

U.K.A.E.A.

Risley, Warrington, Lancs.

Closing Date: April 14, 1960

DUTIES

Post I (Ref. 206/J28)—To control the work of several sections engaged on the design of large chemical projects. The work will include novel and conventional engineering problems arising from the use of special materials and will involve provision for the remote operation of plant and equipment as well as design of associated laboratories and services.

Post II (Ref. 207/J28)—To control the work of several sections engaged on the design of metallurgical and mechanical engineering plant installations. The plants are required to handle unusual metals involving the design of new equipment for vacuum casting, pressing, rolling, heat treatment, machining, welding and powder metallurgy processes.

QUALIFICATIONS AND EXPERIENCE

All applicants must have served a recognised engineering apprenticeship and be corporate members of a senior engineering institution or have equivalent qualifications.

For Post I considerable experience of work at a senior level on high quality mechanical or chemical engineering design is essential and possession of an honours degree in either of these may be an advantage.

For Post II considerable design experience at a senior level in a similar field, but not necessarily in nuclear engineering, is essential. Some experience of constructional work and of plant installation would be an advantage.

TUBE INVESTMENTS RESEARCH AND DEVELOPMENT DIVISION

Tube Investments invite applications for appointment to the scientific and engineering staff of their Technological Centre in Aldridge, Staffordshire. Applicants should be in the age range 24 to 35 years and possess an Honours Degree or its equivalent. Previous industrial experience is desirable but not essential.

Staff are required for process research and engineering development in the following fields:—

1. *Metallurgy* with particular reference to beryllium and other "nuclear" metals including cermets.
2. *Electronics* with particular reference to new techniques of inspection based on eddy current and ultrasonic measurement.
3. *Electrical Engineering* with particular reference to automatic control mechanisms using transistor and other electronic circuits.
4. *Welding* with particular reference to development of new techniques for welding.

The salary offered will be in accordance with age and experience and applications should be addressed to The Director, T.I. Technological Centre, The Airport, Walsall, Staffordshire.

SENIOR DRAUGHTSMAN

required by leading company manufacturing Precision Sheet Metal Instrument Cases for the Electronics and Nucleonics Industries. This appointment offers a first-class opportunity to a Draughtsman with inventive ability able to produce sketches of interesting electronic housings for estimating and production purposes. Excellent working conditions in modern factory. Contributory pension scheme.—Apply in writing giving full details of qualifications, previous appointments and salaries earned, to **Alfred Imhof Limited, Ashley Works, Cowley Mill Road, Uxbridge, Middlesex.**

NUCLEAR ENGINEERING

Development Engineers required for work on novel projects connected with nuclear and conventional steam-generating plant.
Applicants should preferably hold a mechanical or chemical engineering degree and should have some previous experience of the practical aspects in design or development of heat exchangers and high-pressure steam plant.
Commencing salary in range £900–£1,200 per annum.
Contributory Pension Scheme.
Applications should be made in writing, giving details of age, qualifications and experience, to:

Staff Manager,
Foster Wheeler Limited,
3 Ixworth Place, London, S.W.3

Telephone your classified advertisements to **MUSeum 8252**

SITUATIONS VACANT

WANTED 677 Trainee Engineers

The Electricity Supply Industry has vacancies this year for 677 recruits to its engineering training schemes. They are required both by the Central Electricity Generating Board and by the 12 Area Electricity Boards.

83 university graduates are needed as graduate trainees. They should possess a degree in electrical or mechanical engineering of a British university.

73 technical college graduates are required as engineering trainees. They should possess a Diploma in Technology, a College Diploma, a Higher National Diploma or a Higher National Certificate in electrical or mechanical engineering.

521 school-leavers are needed as student apprentices. There are two levels of entry: for those who possess a good Ordinary level G.C.E., including passes in maths and science, and for those who have taken G.C.E. at "O" level and have also obtained passes in maths and physics at Advanced level.

Training for university and technical college graduates is by means of a planned two-year course of practical experience, satisfying the requirements of the professional institutions.

Training for school-leavers is by means of a five-year apprenticeship, including day-release or a Sandwich Course, leading to a professional engineering qualification.

On satisfactory completion of training, all trainees are guaranteed employment in this essential, expanding industry. A wide range of careers is available in many types of engineering – generation, transmission, distribution, commercial and research. Because the demand for electricity doubles every ten years, the prospects of promotion are good.

For further information write to:

The Education and Training Officer,
The Electricity Council,
Winsley Street,
London, W.1

EDUCATIONAL

THE UNIVERSITY OF MANCHESTER
POSTGRADUATE COURSE IN NUCLEAR ENGINEERING

This course, which is of one year's duration, is intended for graduate engineers, physicists, or metallurgists who wish to specialise in the field of Nuclear Engineering. Students attend a course of lectures on the fundamentals of the subject, supplemented by selected topics at a more advanced level, and also undertake an experimental project. The Diploma for Advanced Studies in Science is awarded to candidates who successfully complete the course. Application has been made to the Department of Scientific and Industrial Research for acceptance of the Postgraduate Course in Nuclear Engineering as suitable for the tenure of its Advanced Course Studentships.

All applications and enquiries should be addressed to Professor W. B. Hall, Nuclear Engineering Laboratories, The University, Manchester 13.

IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY
(UNIVERSITY OF LONDON)
POSTGRADUATE COURSE IN NUCLEAR POWER

A full-time postgraduate course in nuclear power is held each year at Imperial College. This course is conducted from the engineering point of view and is intended primarily for graduate engineers and applied scientists who wish to pursue a career in the design, development and construction of nuclear power stations. A special feature of the course is the inclusion of a design study of a complete nuclear power project. Experimental work will include the use of a natural uranium-graphite exponential assembly.

Further information may be obtained on application to the
REGISTRAR, IMPERIAL COLLEGE, LONDON, SW7

UNITED KINGDOM ATOMIC ENERGY AUTHORITY
require an
ASSISTANT ENGINEER
and
ASSISTANT PHYSICIST
at their Nuclear Power Station at Chapelcross, near Annan, Dumfriesshire.

(a) The Engineer post entails investigation of problems arising from the operation of a nuclear reactor station; engineering experiments and the provision of a calculation and specification service. Corporate membership of a recognised senior engineering institution, or an Honours Degree in Engineering or an equivalent qualification is required together with some previous industrial or research experience.

(b) The Physicist posts entail the study of theoretical aspects of nuclear reactor and plant operation and safety; design, construction and operation of laboratory pilot rigs and experiments; experimental work on nuclear plant performance and evaluation.
An Honours Degree or equivalent in Physics or Applied Mathematics and some appropriate industrial experience are essential.

SALARY: Between £860 (at age 25) and £1,340 per annum.
Contributory Superannuation.
Staff Housing Scheme.

Applications to Personnel Manager at above address quoting reference G23/J28, giving full details of age, education, qualifications, experience, present post and present salary.
Closing date: 28th March, 1960.

TRADE ANNOUNCEMENT

FLUORESCENT GLASS

This material is of great potential interest for scintillation counters for detecting alpha, beta and gamma radiations. It has been developed by The British Scientific Instrument Research Association and can now be manufactured and supplied by

Levy West Laboratories Ltd.,
Wembley Hill Estate, Wembley, Middlesex

AT YOUR SERVICE

MAY WE HELP YOU?
THE BALFOUR GROUP OF COMPANIES

Aeronautical, Nuclear, Electronic and General Engineers.
Special purpose machines and controls, gauge, tool and pattern manufacturers

OFFER A COMPLETE SERVICE

Design, Drawing, Planning, Development, Machining up to 60 in. diameter in Stainless, Monel, Nimonic, High Tensile Steel, Aluminium etc.
Welded Fabrications from 1 in. to 40 ft long.
Die Sinking, Spraying, General Finishes, Heat Treatment, and Assembly.

PROTOTYPE & PRODUCTION REQUIREMENTS

For prompt attention write, 'phone or Telex

BALFOUR (MARINE) ENGINEERING CO. LTD.
290/296 High Road, Ilford, Essex
ILFORD 6111 TELEX
7 lines (PBAX) 22302

Fully Approved Ministry of Supply (A.I.D.), D.G.I., A.R.B., I.E.M.E. On Official Manufacturing Lists and Approved Tenderers to—U.K.A.E.A.

AT YOUR SERVICE

when you need an expert

TRANSLATIONS
French and all other languages, from or into English. Specifications, research, publicity, correspondence.
Olympia Translation Service
29 Russell Gardens,
London, N.W.11. Tel.: MEA 2282

DESIGN TEAMS
available for plant and mechanical engineering projects in the nuclear field
•
NORRIS BROTHERS LTD.
53 Victoria Street, London, S.W.1
Telephone : ABBey 6132

X-RADIOGRAPHY
of welds and castings offered up to 1¼" thickness, also high vacuum test facilities.
IMMEDIATE SERVICE
THOS. RYDER & CO. MANCHESTER LTD.,
COMMERCIAL STREET WORKS,
KNOTT MILL, MANCHESTER 15
Central 6753

SHEET METAL WORK
All Materials · Skilled Work
MABBOTT & CO. LTD.
EST. 1901
SHEET METAL DIVISION
Phoenix Works, Poland Street,
Manchester, 4. Collyhurst 1773

C. W. GARRETT & SON
for
ALL DRAWING OFFICE SERVICES, PROCESSES, MATERIALS AND EQUIPMENT
•
WINDMILL ROAD, BRENTFORD
MIDDLESEX
Telephone : ISLeworth 4433 (4 lines)

WE MAKE TANKS, FRAMES, DUCTS, INSTRUMENT PANELS & CHIMNEYS
Let us have your enquiries for welded fabrications large or small. And we can press 200 Tons, guillotine ¼ in. plate, bend and cylindrical roll.
SHELMERDINE & MULLEY LTD.,
Edgware Road, Cricklewood,
N.W.2
GLAdstone 7677-8

MANCUNA ENGINEERING LTD
DENTON, MANCHESTER
SPECIALISTS IN GAS CLEANING AND DUST TECHNOLOGY
District Office:
59 Victoria Road, Surbiton, Surrey
Tel: ELMbridge 9793

R. & J. PARK LTD
Dominion Works, Chiswick
England
•
Export packers, shippers and forwarding agents. Specialists in packing heavy machinery

ALUMINIUM DESIGN
and fabrication service available for all types welded and other light alloy structures and components
ALPHAMIN LTD.
4 Dunston Street, Kingsland Road,
London, E.8. Tel.: CLIssold 4161

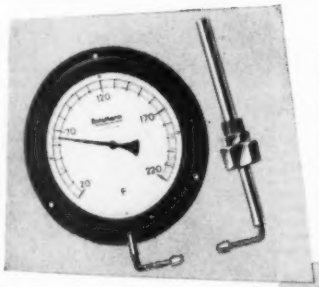
Electrical windings on production basis, F.H.P. armatures, stators, transformers, resistance tubes, Solenoid coils, chokes, etc.
Immediate attention to all enquiries
KENSAL ELECTRICS LTD
151 Kensal Road, London, W10
LAD 4530

Tick No 188 on reply card for further details

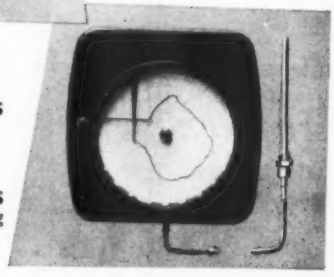
Tick No 189 on reply card for further details

Rototherm

MERCURY-IN-STEEL TEMPERATURE INSTRUMENTS



DIAL THERMOMETERS for Industrial purposes.
DIAL THERMOMETERS for Diesel engine use.
INDICATOR CONTROL THERMOMETERS with Electric Contact Head.
MAX. or MIN. INDICATORS.



TEMPERATURE RECORDERS
Single or Dual Pen.
Fixed or Portable Models.
TEMPERATURE CONTROLLERS
Indicating and Non-Indicating

Also a full range of BI-METAL and VAPOUR PRESSURE Temperature Instruments.
Write for details
THE BRITISH ROTOTHERM CO. LTD.
Merton Abbey, London, S.W.19. Telephone: LIBerty 7661 (6 lines)

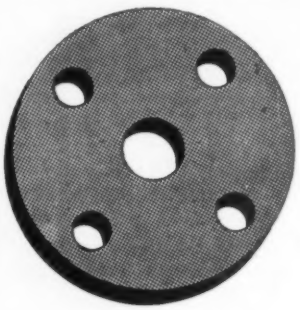
LARK TUBE CLEANERS

Clean round the bend—

with
'1000' SERIES
Motors & Heads for 2"-5" Tubes
Write for catalogue showing the full range of 'Lark' tube-cleaning equipment.

INDUSTRIAL DESCALING TOOLS LTD
Sole distributors for the manufacturers H. WILLIAMS & SON LTD
LARK WORKS, SANDRIDGE ROAD, ST. ALBANS, HERTS.
Telephone: St. Albans 56026 Telegrams: Descaltool, St. Albans

Tick **No 190** on reply card for further details



STAINLESS TUBES & FLANGES

We offer in approved grades of Stainless Steel

- ★ FLANGES MACHINED TO B.S. TABLES OR TO SPECIAL SIZES
- ★ SOLID DRAWN TUBES—FABRICATED PIPES
- ★ ROUND and HEXAGON BAR
- ★ PROFILES CUT TO ANY THICKNESS OR SIZE
- ★ CASTINGS TO CUSTOMERS SPECIFICATION

Keen Prices — Prompt Delivery

Send enquiries to Dept. N.P.

STAINLESS STEEL PROFILE CUTTERS LTD.

Farfac Works, Kings Grove, MAIDENHEAD. *'phone* 1522/23.

ADVERTISERS IN THIS ISSUE

Airmec Ltd. 82
Allen & Sons (Tipton) Ltd., W. G. 168
Alsthom 27
Appleby & Ireland Ltd. 207
Armstrong Patents Co. Ltd. 72
Associated Lead Manufacturers Ltd. 57
A.T.E.N. 14
Atomics International 83
Aubert et Duval 34
Avo Ltd. 75

Baker & Bessemer Ltd., John 170
Barlow-Whitney Ltd. 194
Berry & Co. Ltd., Henry 190
Bettles & Sons Ltd. 208
Bitulac Ltd. 174
Bolton Gate Co. Ltd. 202
Bouëllat (Chaudières) 22
British LaBour Pump Co. Ltd. 197
British Paints Ltd. 80
British Rototherm Co., Ltd., The 213
Bristol Siddeley Engines Ltd. 167
Bristol Siddeley Engines Ltd. (Beaver Ball Div.) 181
Bronx Eng. Co. Ltd. 184
Budd Co., The 47

Central Electricity Generating Board, The 106
Colvilles Ltd. 92
Compagnie Francaise Thomson-Houston 33
Compagnie Generale De Telegraphie Sans Fil 28
Compagnie Industrielle Des Téléphones 25
Consett Iron Co. Ltd. 55
Consolidated Pneumatic Tool Co. Ltd. 58, 59
Constructions Radioélectriques et Electroniques Du Centre 31
Crosby Valve & Eng. Co. Ltd. 187

Darlington Forge Ltd., The 81
Darlington Insulation Co. Ltd., The 199
Detel Products Ltd. 178
Dewrance & Co. Ltd. 98
Distillers Co. Ltd., The 12
Donkin Co. Ltd., The Bryan 192
D.P. Battery Co. Ltd., The 48

Edwards High Vacuum Ltd. 54
Electrolube Ltd. 210
Electronic Associates Ltd. 6
Electronique Appliquée, L' 19
E.M.B. Co. Ltd. 71
E.M.I. Electronics Ltd. 161
E.M.I. Electronics Ltd. (Instrument Div.) 185
Endecotts (Filters) Ltd. 210
E.R.T.N. 34
Evans & Son (Portsmouth) Ltd., J. 60

Fielden Electronics Ltd. 171
Fielden Electronics Ltd. (Pressure Div.) 206
Fonderie de Gentilly 30
Forges et Ateliers de Jeumont 36
Frazer & Hansen Ltd. 201

General Electric Co. Ltd., The 189
General Electric Co. Ltd. (Heavy Metals Div.) 201
General Electric Co., International 94, 95
Glaswerk Schott 77
Graviner Mfg. Co. Ltd. 168
Grosvenor & Co. Ltd., Richard 208
Groupement Atomique Alsacienne Atlantique 17

Harvey & Co. (London) Ltd., G. A. 52
Head Wrightson Processes Ltd. 173
Heather Filters Ltd. 204
High Voltage Eng. Corp. 153
Hilger & Watts Ltd. 209
Hispano Suiza 30
Hoffman Mfg. Co. Ltd., The 176
Honeywell Controls Ltd. 45
Howden & Co. Ltd., James 215

I.E.A. Exhibition 176
Imperial Chemical Industries Ltd. (Metals) 104
Industrial Descaling Tools Ltd. 213
Industries Atomique 14
International Machine Tool Exhibition 174

K.D.G. Instruments Ltd. 190
Keith Blackman Ltd. 73
Keyswitch Co. Ltd. 175
Kirk & Co. (Tubes) Ltd. 186
Kodak Ltd. 53

Labinal Electronique 20
Laboratoire Industriel d'Electronique Belin 21
Lafarge Aluminous Cement Ltd. 205
Lang Pneumatic Ltd. 39
Lead Development Assoc. 208
Lewis, H. K. 162
Lincoln Electric Co. Ltd. 99
Lyons Ltd., Claude 184

Magnesium Elektron Ltd. 97
Mallinckrodt Nuclear Corp. 90
Mallinson & Sons Ltd., William 188
Manganese Bronze & Brass Co. Ltd., The 8
Masson et Cie 163
Marston Excelsior Ltd. 177
M.B. Metals Ltd. 196
Metal & Pipeline Endurance Ltd. 180
Miles Hivolt Ltd. 200
Mitchell Engineering Ltd. 78, 79
Morris, Ltd., B.O. 85, 202
Murex Ltd. 192

Newalls Insulation Co. Ltd. 86
N.G.N. Electrical Ltd. 196
Nuclear Equipment Ltd. 216
Nuclear Materials & Equipment Corp. 164
Nuclear Power Plant Co. Ltd. 166
Nuclear Power Year Book & Buyers Guide 50, 51

Osborn & Co. Ltd., Samuel 91
Owen Organisation, The 89
Oxley & Co. Ltd., William 74

Palatine (Surbiton) Ltd. 198
Pascall Eng. Co. Ltd., The 210
Paterson Hughes Eng. Co. Ltd. 66
Payne & Griffiths Ltd. 182
Payter & Co. Ltd., E. C. 182
Pechiney 18
Pitman 162
Plannair Ltd. 84
Powell Duffryn Carbon Products Ltd. 165
Power Auxiliaries Ltd. 102
Progil 38
Pye Ltd. 49
Pyrene Co., Ltd., The 203

Q.V.F. Ltd. 56

Radiac 35
Radiospares Ltd. 188
Rawlplug Co. Ltd., The 40
Research & Control Instruments Ltd. 194
Rio Tinto Management Services (U.K.) Ltd. 101
Roberts & Son Ltd., R. E. 46
Robertson & Ferguson Ltd. 65
Rocol Ltd. 64
Rotameter Mfg. Co. Ltd. 172
Rotax Ltd. 188

Saint-Gobain 4, 23
S.A.M.E.S., S.A. 200
Sangamo Weston Ltd. 206
Sankey-Sheldon Ltd. 11
Screw Machine Products Ltd. 208
Serck Radiators Ltd. 88
S.F.I.M. 36
Shell Mex & B.P. Ltd. 42, 43
Short Bros. & Harland Ltd. 169
Siersatom 32
Simmonds Ltd., L. E. 210
Simon-Carves Ltd. 41
Simplifix Couplings Ltd. 157
Smith & Sons Ltd., Sydney 209
S.N.E.C.M.A. 37
Societe D'Applications Industriells De La Physique 33
Société Des Forges et Ateliers Du Creusot 15
Société Industrielle De Combustible Nucléaire 24
Société Rateau 30
Solartron Electronic Group Ltd., The 2, 67, 68, 69, 70
Spanner Boilers Ltd. 193
Spencer Chemical Co. 44
Société de Recherches & d'Applications Techniques 16
Stainless Steel Profile Cutters Ltd. 214
Stainless Steel Wire Co. Ltd. 172
Staveley Iron & Chemical Co. Ltd., The 204
Stewart & Lloyds Ltd. 87
Stillite Products Ltd. 191

Taylor, Taylor & Hobson 180
Techniques Nucléaires 26
Teddington Aircraft Controls Ltd. 7
Texas Instruments Inc. (Metals & Control Div.) 13
Thermal Syndicate Ltd., The 170
Tilghmans Ltd. 179

Ultra Electronics Ltd. 195
Union Carbide Ltd. 178
Unit Superheater & Pipe Co. Ltd., The 61
Universal Boilers & Eng. Co. Ltd. 96

Vacu-Blast Ltd. 186
Vallourec, S.A. 29
Vokes Ltd. 93

Wakefield-Dick Industrial Oils Ltd. 159
Wandleside Cable Works Ltd. 76
Weston & Co. Ltd., Charles 183
Widnes Foundry & Eng. Co. Ltd. 155
Wiggin & Co. Ltd., Henry 9
Williams & James (Engineers) Ltd. 198
Worthington-Simpson Ltd. 10

The original WINDSCALE

plant, with the first full-scale atomic piles in this country had 16 high-efficiency blowers of great capacity, each absorbing 2,500 h.p. These were supplied by

HOWDEN

For the new advanced gas-cooled reactor AT WINDSCALE

Howden have been chosen to supply four main CO_2 circulators having the following features:—

(1) Inlet Vane Control giving stable operation over full operating range.
(2) High-efficiency aerofoil-bladed radial-flow Impeller and Diffuser.
(3) Oil-bath Bearings.
(4) 1570 h.p. constant-speed A.C. Motor
(by Laurence Scott & Electro Motors Ltd.).
(5) Special Cooling Arrangements.
(6) Entire assembly enclosed in Pressure Bell.

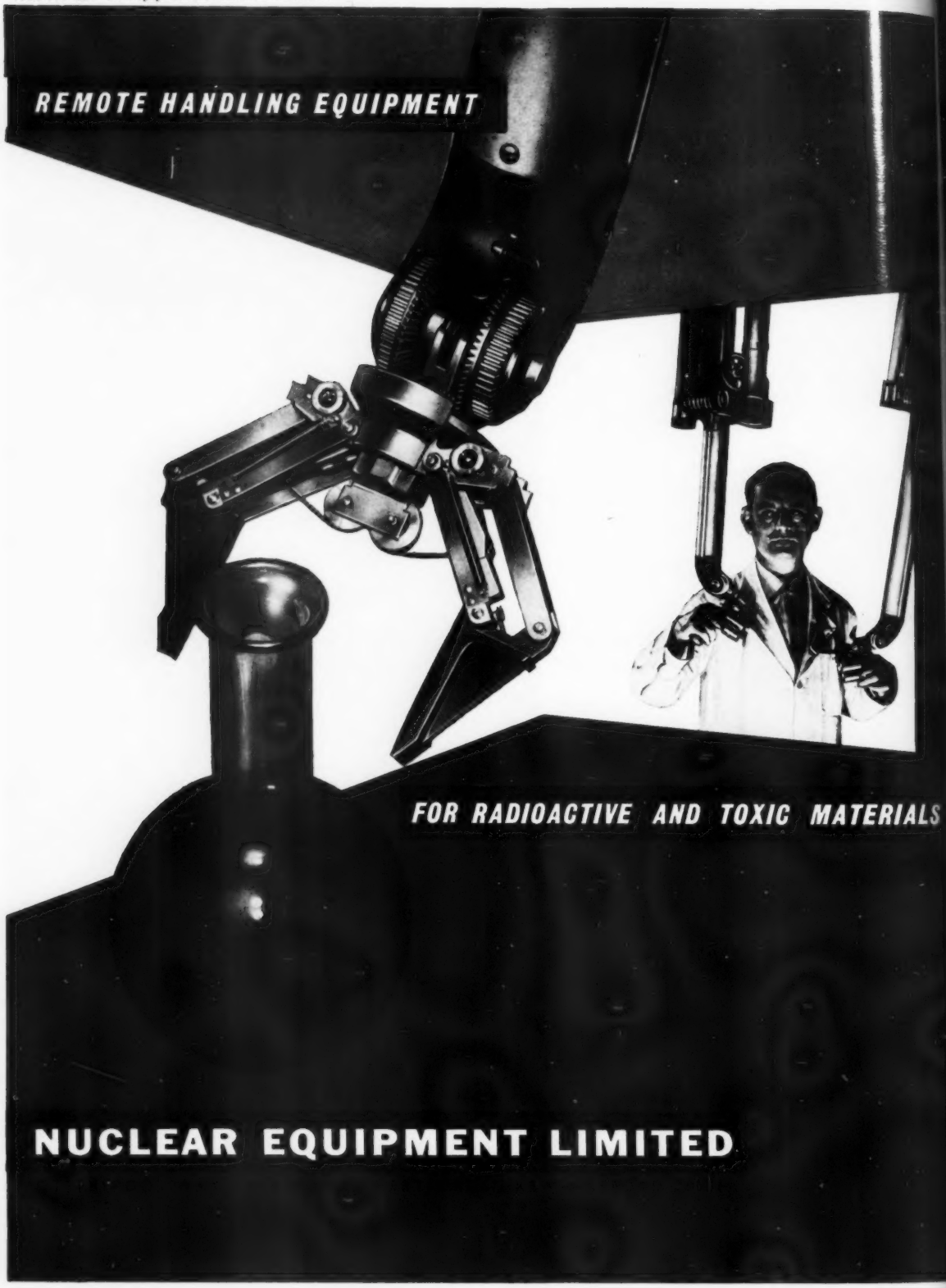
This novel arrangement of circulator requires aerodynamic, heat transfer, and mechanical design of extremely high quality.

A factor influencing the selection of Howden for this important contract is their extensive experience in all these aspects of design and of the manufacturing problems involved.

JAMES HOWDEN AND COMPANY LIMITED
195 SCOTLAND STREET, GLASGOW, C.5, and 15 GROSVENOR PLACE, LONDON, S.W1.

HOWDEN

Tick **No 207** on reply card for further details



VIRGIN